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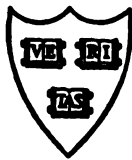
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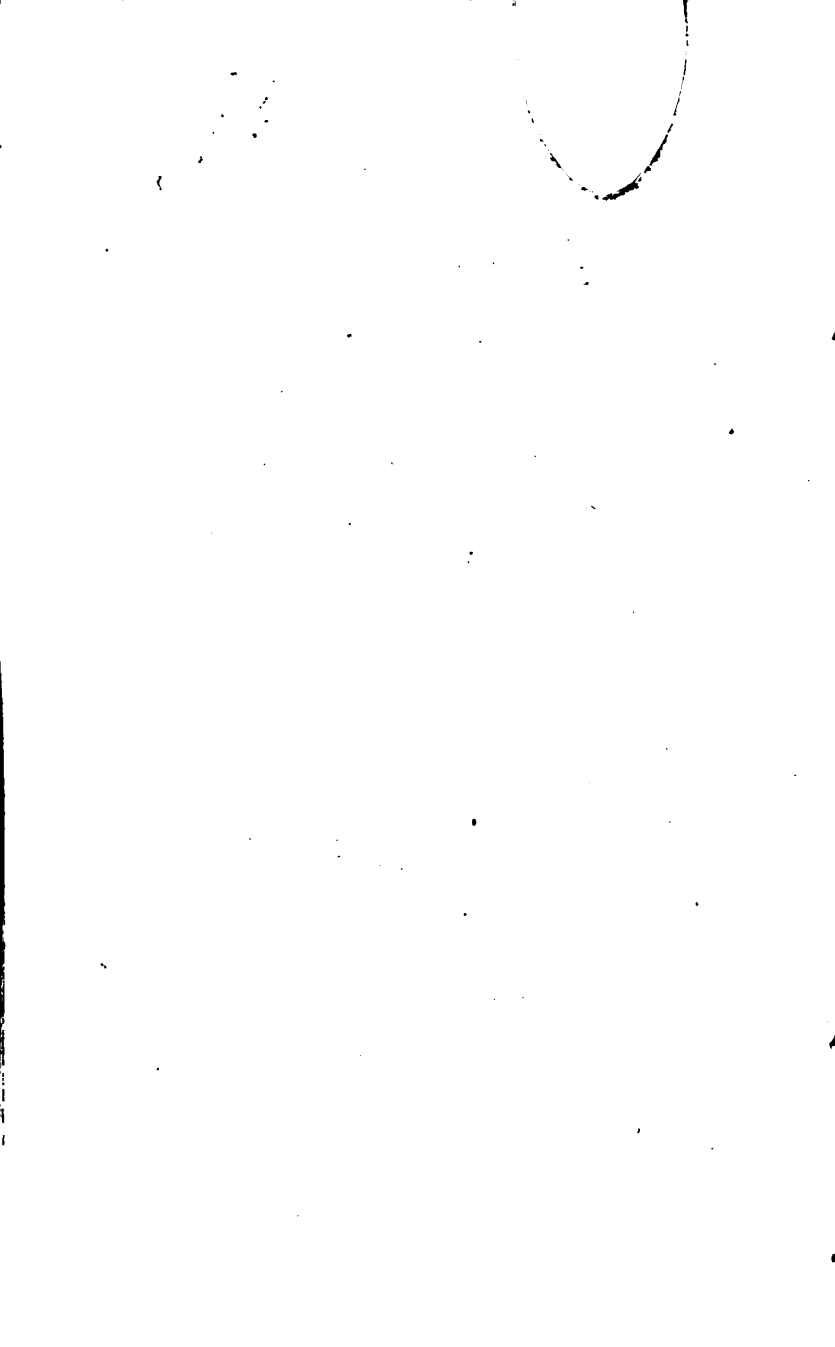
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◦ ELEMENTS
OF
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FOR THE USE OF
SCHOOLS.

BY
JOHN JOHNSTON, M.A.,
PROFESSOR OF NATURAL SCIENCE IN THE WESLEYAN UNIVERSITY.

ILLUSTRATED BY NUMEROUS ENGRAVINGS

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## PREFACE.

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THE design of this work, which has been prepared at the suggestion of a number of experienced teachers, is to supply a lack that has for some time been felt, and which seems to be increasing. In the multitude of Academies, which are everywhere springing up in our country, there are very many from which it is felt that this important science cannot be entirely excluded, and yet but a very limited time can usually be devoted to the classes in it; consequently the text-books now in general use are found either too large and full, or else of too juvenile a character. But while special regard has been had to the wants of such, it is believed that the work will also be found well adapted for the use of that younger class of learners, who may be desirous of making themselves acquainted with the elements of the science, preparatory to the more thorough study of it in the larger works.

The author's larger work has now been before the public a number of years; and the cordial reception it

has met with has afforded him great encouragement in the labor of preparing the present one, which is in part an abridgement of the former. The arrangement of some of the topics discussed has been considerably changed, as was required by the more elementary character of the present work.

Besides many of the best scientific journals, most of the standard English and French authors have been freely consulted, and some of the German, especially the excellent treatise of Mitscherlich ; and, small as is the compass of the volume, the author flatters himself that it will be found a faithful compendium of the science in its present state ; and a useful auxiliary in promoting the study of this his favourite science.

MIDDLETOWN, CT., Dec. 1, 1849.

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# ELEMENTS OF CHEMISTRY.

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## PART I.

### THE IMPONDERABLE AGENTS.

#### INTRODUCTION.

1. THE science of material nature may be conveniently divided into the three great branches—Natural History, Natural or Mechanical Philosophy, and Chemistry.

2. The first of these branches, Natural History, includes three distinct sciences—Mineralogy, or the science of minerals—Zoology, or the science of animals—and Botany, or the science of plants.

3. Natural Philosophy treats of the properties of matter considered in masses, and the relation of these masses to each other, without reference to their internal composition or structure.

4. Chemistry, on the other hand, takes into consideration the internal structure and composition of bodies, and the relations which their ultimate particles sustain to each other. It makes us acquainted with the action of these particles

---

1. Into what three branches may the science of material nature be divided?

2. What are the three subdivisions of the first great branch, or Natural History?

3. Of what does Natural Philosophy treat?

4. With what does the science of Chemistry make us acquainted?

upon each other, and the laws and results of this action;—an action which takes place only between the particles of different kinds of matter, and at distances so very minute as to be entirely insensible, and which always results in the production of compounds possessing new properties.

5. *Subdivision of Chemistry.*—Chemistry is usually divided into the two branches of Inorganic and Organic Chemistry. Inorganic Chemistry treats of mineral matter, or matter uninfluenced by the principle of life; while Organic Chemistry treats of matter under the influence of this principle; that is, it treats of animal and vegetable matter.

6. As a general truth, organic substances cannot be produced by art, without the aid of the living principle. As an instance, sugar is a compound of carbon (pure charcoal) and water, or the elements of water; but no chemist can take these substances in his laboratory, and cause them to unite so as to produce sugar. It is only from vegetable or animal substances that sugar can be formed.

7. *Atoms, or Molecules.*—It is believed that every kind of matter is made up of immense numbers of minute particles, which are so small that they have never been seen by the eye, even when aided by the microscope; and to these has been given the name atom (from *a*, primitive, and *temno*, I cut) or molecule. We have little direct knowledge of these particles, and yet it will be seen as we progress, that much has been determined of them indirectly. It is believed that all the particles of the same substance are precisely of the same size, form, and weight.

8. *Simple and Compound Bodies.*—Simple bodies, or

5. What two branches of the science are there, and of what do they treat?

6. Can organic substances be produced by art, unaided by the vital principle?

7. What is said of the atoms or molecules of bodies?

8. When are bodies said to be simple?

elements, are such as are composed of only one kind of particles, of which there are known with certainty only fifty-six. Such are gold, silver, copper, sulphur, carbon, &c.

9. Compound bodies are composed of two or more kinds of particles, which are held in intimate union by a force called chemical attraction or affinity. The separation of the elements of a substance is called its decomposition.

All substances are considered simple that have never been decomposed.

10. The composition of a body may be determined in two ways, analytically or synthetically. By analysis, the elements of a compound are separated from one another, as when water is resolved by the agency of galvanism into oxygen and hydrogen; by synthesis they are made to combine, as when oxygen and hydrogen unite by the electric spark, and generate a portion of water. Each of these kinds of proof is satisfactory; but when they are conjoined—when we first resolve a particle of water into its elements, and then reproduce it by causing them to unite—the evidence is in the highest degree conclusive.

11. *Matter is Indestructible*; that is, it cannot be made to cease to exist. This statement seems at first view contrary to fact. Water and other volatile substances are dissipated by heat; and coals and wood are consumed in the fire, and disappear. But in these and other similar phenomena, not a particle of matter is annihilated, but the apparent destruction is owing merely to a change of form or of composition. The power of the chemist is, therefore, limited to the production of these changes.

12. *Different Forms of Matter.*—Matter exists in three

9. What are compound bodies?

10. How may the composition of a body be determined?

11. Can matter be destroyed by human agency?

12. What are the three forms or states of matter? What is said of the imponderable agents?

forms or states, the solid, liquid, and gaseous. Besides these there are the three imponderable agents, Heat, Light, and Electricity, which, if they are material, will constitute a fourth form of matter.

13. It is believed that the particles of a substance, even the most solid, are never in actual contact, but are held in close proximity by the two opposite forces of attraction and repulsion; and that the particular state, whether solid, liquid, or gaseous, in which a body is seen, depends upon the relative intensity, for the time, of these forces.

14. If the force of attraction altogether preponderates in a body, it is *solid*, and the particles, in general, are held firmly in their places, and are incapable of motion among themselves. But the particles are not in actual contact, for, by cooling, or by great pressure, the dimensions of any body may be contracted, and, therefore, its particles brought nearer each other. This will appear more fully hereafter.

15. In *liquids*, there is a degree of cohesion among the particles, which, however, are capable of perfectly free motion among each other. That there is a degree of cohesion existing between the particles is shown by the drop, which is composed, of course, of particles, held together by a slight force; but this slight force does not seem to interfere with the freedom of their movements.

Liquids have been supposed to be inelastic, but it has been found by accurate experiments, that they are slightly elastic.

16. *Gases* are distinguished by their tendency to expand,

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13. Upon what does the particular form of a body depend?

14. Are the particles of solids in actual contact? What are the reasons for this opinion?

15. Is there any cohesion among the particles of liquids? How is this shown? Are liquids elastic?

16. How are gases distinguished? Is there any cohesion among their particles?

or enlarge their volume, when external pressure is removed. In them the attractive force is entirely overcome by the repulsion of the particles. The term *fluid* is applied to both liquids and gases.

17. Some substances are found naturally existing in one of these states, and some in another; and many can be made to pass from one state or form to another, simply by varying their temperature, or the pressure to which they are exposed. Thus, water at a moderate temperature is liquid, but in the cold weather of winter it freezes, that is, becomes solid; and if it be heated sufficiently, it is changed into steam, or becomes gaseous. The metal, platinum, is found always in the solid state, but it may be melted by very great heat; it cannot, however, be changed into a gas by any heat that man can produce. Several substances, found naturally in the gaseous state, may be changed to liquids by great pressure, or by extreme cold; and, by a still greater cold, some of them may be frozen. Others, as atmospheric air, have hitherto resisted all attempts to reduce them to the liquid or solid form.

18. It has already been remarked, that, if the imponderable agents be considered as material substances, they constitute a fourth form of matter. They are said to be imponderable, because they possess no appreciable weight; but they certainly exhibit some of the ordinary properties of matter. They may be accumulated in bodies, are capable of being attracted and repelled, and often produce various chemical and mechanical effects. But because they possess no weight, so far as we can determine, many choose to consider them, not as matter, but only properties of matter.

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17. How may a substance be made to pass from one of these forms into another? What example is given? What is said of the metal, platinum?

18. Why are the imponderable agents so called? Do they exhibit any of the proportions of matter?



## HEAT.

## NATURE AND SOURCES OF HEAT.

19. *Nature of Heat.*—We know nothing of the real nature of heat, but are familiar with many of its relations to matter in general, and with its effects. Even when the nicest balances are used, it seems to be entirely destitute of weight; any substance always weighing precisely the same, whether at a high or a low temperature.

20. On this account many have doubted whether it is a substance, but consider it as a mere property of matter. In describing its effects, however, and its various relations to matter in general, we shall speak of it as an exceedingly subtle fluid, the particles of which constantly repel each other, but are attracted by other substances;—as capable of being transmitted through space, and the interior of bodies, and of being accumulated in quantities in them. We mean by the use of the word, the cause, whatever it may be, of the effects attributed to it.

21. *Sources of Heat.*—The chief sources of heat are the five following, viz.: 1. The sun; 2. Combustion; 3. Friction; 4. Electricity; 5. Vital action.

22. *The Sun* is the great source of heat to our system. The intensity of the solar heat appears to be directly in proportion to the number of rays that can be collected upon a given surface; and at one time philosophers were able to produce a greater heat by collecting the sun's rays by means of the convex lens or concave mirror, than by any other mode.

19. Do we know anything of the real nature of heat?

20. In describing the effects of heat, and its relation to matter, what do we consider it? What do we really mean by the use of the word heat?

21. What are the chief sources of heat?

22. What is said of the heat of the sun?

But although the sun's rays are not made use of in the arts when great heat is required, yet their momentous importance to all the inhabitants of the earth cannot be overestimated. Without them all the water upon the face of the globe would soon be congealed, and animal and vegetable life cease to exist.

23. *Combustion* is the great source of artificial heat, as the sun is the source of natural heat. Besides wood, nature has provided immense deposits of combustible material, in the form of mineral coal, in the bosom of the earth. These are found in almost every country, and seem to be provided by the Creator as an unfailing resource for man, when, from the increase of the species, or from his own negligence or extravagance, the supply from the vegetable world should fail or become deficient.

24. *Friction* is occasioned by the rubbing of one substance against another, and is usually attended by the evolution of heat. By the friction of the parts of heavy machinery, especially when not well oiled, heat has often been evolved sufficient to ignite wood; and the same effect is said to have been produced in ships by the rapid descent of the cable. Some tribes of the aborigines of this country were accustomed to kindle their fires by rubbing smartly one piece of wood against another.

In the boring of cannon heat enough has been evolved to raise the temperature of a considerable quantity of water so as to boil.

The friction of liquids or gases against other substances does not appear to excite heat.

23. What is the chief source of artificial heat? How has nature provided a large supply of fuel for the production of heat artificially?

24. What is said of friction as a source of heat? What is said of the effects of friction in machinery?

## 16 EXPANSION OF BODIES BY HEAT.

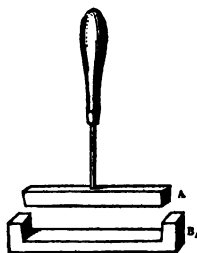
25. *Electricity*, in passing through poor conductors, or good conducting substances which are small in proportion to the quantity of fluid passing through them, often intensely heats them; but this subject will be discussed further on.

26. The influence of *vital action* in developing heat is seen in all warm-blooded animals, which are maintained at a temperature often much above that of the air and other surrounding bodies, though heat must constantly be escaping from them.

### EXPANSION OF BODIES BY HEAT.—THERMOMETERS.

27. We have seen above (17), that heat is capable of changing the form of bodies, as from the solid to the liquid, and from the liquid to the gaseous state; but before this change is effected, on the application of heat to nearly all bodies they are expanded or enlarged, and contract again on cooling.

The heat appears to enter among the particles of the body, separating them farther from each other in opposition to cohesion, and thus rendering them less compact than before.



28. *Expansion of Solids*.—The expansion of solids by heat is not very considerable, but may easily be made very sensible. Let a bar of brass, A (see fig.), be accurately fitted into a gauge, B, when cold, and then let it be slightly

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25. In what circumstances does the passage of electricity excite heat?

26. What is said of vital action as a source of heat?

27. What is the general effect of heat on the dimensions of bodies? How is the expansion produced?

28. Describe the experiment showing the expansion of a piece of metal by heat. Does the metal expand in breadth and thickness, as well as in length?

heated; it will be found to have increased so much in length as not to fit the gauge. If the gauge be also made of brass, upon cooling it in ice-water the same result will be obtained, because of the contraction of the gauge by the cold.

Though these experiments show a change in length only, a corresponding change is at the same time produced both in breadth and thickness.

29. But all solids do not expand equally when equally heated; lead, for instance, expands more than brass, and brass more than iron. The expansion is not permanent, but when subsequently cooled the body returns to the same dimensions as at first.

The expansion of bodies by heat, and also their contraction on cooling, appears to take place with a force that is absolutely irresistible.

30. The different expansibility of the two metals, copper and platinum, may be shown by soldering together a thin slip of each, and applying a moderate heat to the compound bar. Both plates will be equally heated, but the copper being the most expansible, the bar will be curved, the copper being on the convex side. See figure, in which the copper is supposed to be on the lower, and the platinum on the upper side.



This property of bodies, and particularly of the metals, has been applied to various useful purposes in the arts. The iron band or *tire* of a carriage-wheel is made a little smaller than the circumference of the wheel, but, being expanded by

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29. Do all solids expand alike? Is the effect permanent? Is the expansive force irresistible?

30. Describe the experiment showing the different expansions of two metals. Describe the mode of applying the tires of carriage-wheels.

## 18 EXPANSION OF BODIES BY HEAT.

heat, is sufficiently enlarged to be slipped on; and the immediate application of water prevents it from burning the wood, and brings the iron to its original dimensions, causing it to grasp the wheel with great firmness. Other examples will suggest themselves to the mind of the student.

31. The expansions and contractions of bodies by changes of temperature also occasion some inconveniences. The accurate movement of clocks depends upon the length of their pendulums, which being sensibly affected by changes of temperature, they are made to go faster in cold, and slower in warm weather.

32. Brittle substances, when unequally heated, are often broken by the unequal expansions and contractions to which they are liable.

Boiling water, poured upon a plate of glass, is very sure to break it, because the upper surface being at first more heated, and therefore more expanded than the lower, it tends to bend it like the compound bar (30), but being a brittle substance, and not capable of bending, it is fractured.

Metallic or other instruments used for measuring length or capacity vary with change of temperature—a circumstance that sometimes occasions serious difficulty where very great accuracy of measurement is required.

33. *Expansion of Liquids.*—In solids, the expansive force of heat is opposed (14) by the cohesion of their particles, and is therefore less effective than in liquids, in which there is only a very slight cohesion of the particles. A liquid, therefore, will expand on being heated, much more than a solid.

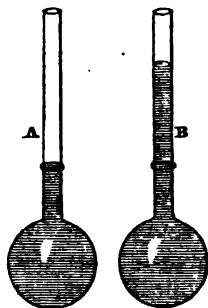
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31. What inconveniences result from the expansion of bodies by heat, and their subsequent contraction?

32. Why will a plate of glass be broken by pouring boiling water upon it?

33. Why should a liquid be expanded by heat more than a solid?

34. The expansion of a liquid may be shown in the following manner. Take a glass flask (called a matrass or bolt-head), of the form represented in the figure, and partly fill it with some liquid, as water, and tie a thread around the stem, as on A, to indicate the height of the water in it; and then apply for a few minutes the heat of a spirit-lamp. Both the glass and the water will be expanded; but the water will expand more than the glass, and will then rise in the stem, as shown in B.



35. But all liquids when equally heated do not expand alike,—every one possesses an expansibility peculiar to itself. By experiment, it is found that ether expands more than alcohol, alcohol more than water, and water more than mercury.

36. It is found that both solids and liquids expand more by a given addition of heat at high than at low temperatures; that is, when very hot, if they are heated a given amount, they expand more than when the same amount of heat is added to them at a lower temperature.

37. *Expansion of Gases.—Thermometers.*—Gases are expanded by heat more than either solids or liquids. This is supposed to be in consequence of the total want of cohesion (16) among their particles.

34. Describe the experiment to prove that water expands when heated more than glass.

35. Do all liquids expand alike when heated?

36. Do bodies expand most at high or low temperatures, when heated a given amount?

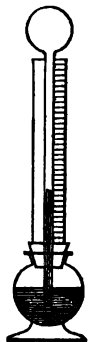
37. What is said of the expansion of the gases? What reason is given for this fact? Describe the method of showing the expansion of air by heat.



To show the expansion of air by heat, let a glass flask, filled with air, be placed as in the figure, with its mouth immersed in water; then warm it slightly, by grasping the bulb in the hands, or breathing upon it, when the air will escape in bubbles, in consequence of its expansion by the heat. On cooling, the air within contracts, and the water rises in the stem to supply the place of the air which was expelled.

38. All gases, whatever may be their nature, expand equally when equally heated, and, like solids and liquids, contract again to their original volume when cooled down to the temperature they had at first. So, also, a given quantity of heat, communicated to them at any temperature, produces the same expansion.

39. *Thermometers* are instruments for measuring variations of temperature in the air or other substances. The name is from the two Greek words, *thermos*, heat, and *metron*, a measure. The first instrument of the kind, so far as we know, was constructed but little more than two hundred and fifty years ago, by Sanctorio, an Italian philosopher.



There are several different thermometers in use, but all depend for their action upon the expansion of bodies by heat, and contraction by cold.

40. *Sanctorio's* thermometer was made in the following manner. A glass tube of small diameter, having a bulb blown at one end, was partly filled with a colored liquid, and the stem passed through

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38. Do all gases expand alike by heat? Will the same quantity of heat produce the same expansion at any temperature?

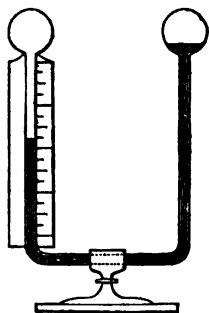
39. What are thermometers?

40. Describe *Sanctorio's* thermometer.

a cork, and inverted in a vessel containing the same kind of liquid, and having a wide bottom, as in the figure, so as to stand upright firmly. Through the cork a small perforation was made, so as to allow the air to pass freely, and to the stem a graduated scale was attached, to mark the rising and falling of the liquid in it.

41. Now, in an instrument of this kind, it is plain that when the bulb is heated, the air within will be expanded, as before explained (37), and the liquid in the stem will fall; and a motion of the liquid in the opposite direction will take place when the bulb is cooled. The rise and fall of the liquid will also be proportional to the change of temperature in the bulb. The instrument, therefore, answered the purpose designed quite well; but it is liable to objections, which, however, cannot here be discussed, and has been entirely superseded by others, which are more convenient to use, and are considered more accurate.

42. The *differential thermometer* may be considered as a modification of the preceding. It consists of a glass tube, bent twice at right angles, with a bulb at each end, and is supported on a stand, as shown in the annexed figure. In the tube is contained a portion of colored oil of vitriol, or other liquid; but both bulbs are left filled with air, and to one of the arms is attached a graduated scale. When both bulbs are equally heated or cooled, this instrument indicates no change; but if one is heated or




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41. How does this instrument show a change of temperature?

42. What may the *differential thermometer* be considered? Of what does it consist? Is any change indicated by this instrument when both bulbs are equally heated or cooled? What is indicated by it?



## 22 EXPANSION OF BODIES BY HEAT.

cooled more than the other, a motion is at once occasioned in the liquid in the stem, the *direction* of which will be readily understood from the explanations already given. This thermometer therefore indicates the *difference* of temperature at any time existing between the bulbs, and hence its name. It is exceedingly delicate, and is especially adapted for some particular purposes.

43. The *common thermometer*, in use everywhere at the present day, consists simply of a glass tube of an exceedingly small bore, with a bulb blown at one extremity, and filled with mercury to about one-third the height of the stem. The air being expelled, the tube is hermetically\* sealed, and the *freezing point* ascertained by holding it a short time in water containing ice, and the *boiling point* by holding it in the same manner in boiling water. It is necessary that these two points should be accurately determined, in order that the indications of different instruments may be compared with each other.

By the term freezing point here, is meant the temperature at which water freezes or ice melts, which, with certain exceptions, is always the same, as will be fully explained hereafter; so, also, pure water always boils at the same temperature, provided attention is paid to certain circumstances to be discussed further on in the work. This temperature is called its boiling point.

44. It will be unnecessary here to give a *minute* description of the method of making thermometers, as, at the present day, they can be everywhere obtained at a very moderate price. "Besides, the construction, though simple in

\* A glass tube is sealed *hermetically* by melting the end by means of the blow-pipe, and thus perfectly closing it. For this purpose the end is usually drawn out into a fine point.

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43. Describe the common thermometer. What are the freezing and boiling points?

44. Are thermometers easy of construction?

theory, is difficult in practice. It requires great tact and dexterity to produce one of very moderate goodness; and without steadily watching the process as performed by another, or previously possessing much practical knowledge in glass-blowing, &c., it would be a vain attempt."—*Faraday's Chemical Manipulation*, p. 144.

45. Having determined the points at which the mercury stands in melting ice, and also in boiling water, and marked them by making a scratch upon the tube with a file, a graduated scale of brass or wood, of equal length with the tube, is attached to it, and it is ready for use.

46. The graduation of the scale of the thermometer is a matter of great importance; and it would be fortunate for us if we had but one, instead of three or more, as is the fact. We have seen (43) that in all thermometers there are two fixed points; and the question now before us is, into how many parts, or degrees, shall the space between them be divided? Unfortunately, this question has been answered differently by different artists, and in a manner entirely arbitrary.

47. *Fahrenheit*, a German artist, whose thermometer is generally used in this country and in England, divided it into 180 parts or degrees, and placed the zero, or the beginning of the scale, 32 degrees below the freezing point; so that the temperature of melting ice or freezing water is 32 degrees, and that of boiling water ( $32 + 180 =$ ) 212 degrees.

48. *Celsius* of Sweden proposed to divide the space into 100 parts, and placed the zero at the freezing point. His

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45. How are the freezing and boiling points marked? What is attached to the tube?

46. What two fixed points are there in the various thermometers? Is the space between these points divided in the same manner in the different thermometers?

47. What thermometer is generally used in this country and in England? Describe the scale of Fahrenheit's thermometer.

48. Describe the scale of the centigrade thermometer.

thermometer is called the *centigrade* thermometer, and is used in France and Sweden, and some other parts of Europe.

49. *Reaumur* divided it into only 80 parts, placing the zero, or beginning of the scale, like Celsius, at the freezing point; of course the boiling point is at 80.

50. Below zero of each of the scales, and above the boiling point, degrees are usually marked, of precisely equal magnitude with those of other parts of the scale. Temperatures below zero are usually indicated by placing a horizontal line before the figures representing the degrees. Thus,  $-12^{\circ}$  means 12 degrees below zero on the scale used.

The numbers 180, 100, and 80, which severally represent the number of degrees on the above scales, are to each other as 9, 5, and 4. Recollecting, therefore, that the zero of Fahrenheit is 32 degrees below that of the other scales, the expert arithmetician will find no difficulty in reducing the degrees of one scale to those of another.

Thus, to convert the degree of temperature indicated by Fahrenheit's scale into its centigrade equivalent, we multiply the degrees above or below  $32^{\circ}$  by 5, and divide by 9. Suppose the temperature by Fahrenheit's thermometer is  $140^{\circ}$ , what is the corresponding degree in the centigrade? *Ex.*:  $140 - 32 = 108$ , and  $108 \times 5 = 540$ , and  $540 \div 9 = 60$ . On Fahrenheit's scale, therefore,  $140^{\circ}$  are equivalent to  $60^{\circ}$  of the centigrade thermometer.

Let us suppose again that the temperature by the centigrade thermometer is  $60^{\circ}$ ; it is required to find the corresponding degree by Fahrenheit's instrument. *Ex.*  $60 \times 9 = 540$ , and  $540 \div 5 = 108$ . To this (108) we must now

49. How is the scale of Reaumur's thermometer divided?

50. How are the degrees above the boiling point and below the freezing point marked? Suppose the temperature by the centigrade thermometer to be  $60^{\circ}$ , how may the corresponding degree in Fahrenheit's thermometer be found?

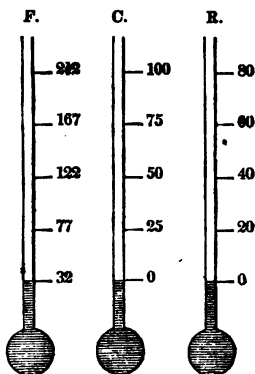
add 32, because the beginning of Fahrenheit's scale is  $32^{\circ}$  below that of the centigrade. Thus  $108^{\circ} + 32^{\circ} = 140^{\circ}$ .

51. In this work, and in most works in the English language, if nothing is said to the contrary, it is always to be understood that temperatures are expressed in degrees of Fahrenheit's scale; but, to avoid confusion, we often place F., C., or R., after the figures expressing the degrees, to indicate what thermometer has been used.

The relation between the three scales above described is indicated in the accompanying figure.

52. The *register thermometer* is a thermometer so contrived as to register the *highest* and *lowest* temperature which may have occurred during the absence of the observer. The one now chiefly in use consists in fact of two thermometers, one being adapted to show the highest, and the other the lowest temperature. For a particular description of the instrument, see the author's larger work, page 38.

53. Though mercury is chiefly used in filling thermometers, yet other liquids are also sometimes employed. At very low temperatures mercury is frozen, so that it ceases to answer the purpose designed; in such cases, therefore, alcohol thermometers alone can be used.



51. How is the thermometer used in a particular case often designated?

52. What is the *register thermometer*?

53. What liquid is used in thermometers for measuring very low temperatures?

54. The *Pyrometer* (from the Greek words *pur*, fire, and *metron*, a measure) is an instrument for measuring heat so intense that the thermometer cannot be used, as the heat of burning coal. The only one now in use is that of Prof. Daniel of London. It is, however, seldom seen, and cannot be here described.

55. *Exceptions to the general Law of Expansion.*—There is a single remarkable exception to the general law (27) concerning the expansion of bodies by heat, as above stated. Water is most dense at the temperature of about  $40^{\circ}$ , and expands, whether it is heated above this point, or cooled below it.



To show this, fill an ounce vial with water at the temperature of  $65^{\circ}$  or  $70^{\circ}$ , and adapt to it a cork, through which passes a glass tube of small bore. Then insert the cork and tube, and fill the latter with water one or two inches above the neck of the vial, and expose the whole to the cold atmosphere of winter; the contraction of the water in the vial will very soon be made evident by the fall of that in the tube; but the falling will shortly cease, and an upward motion commence, indicating an expansion of the water in the vial, although its temperature must be all the time falling. The volume of the water has therefore first been diminished by reduction of its heat, and again expanded; and by making use of the thermometer, it is found that the change takes place at about  $39^{\circ}$  or  $40^{\circ}$ .

By immersing the vial in a freezing mixture, to be here-

54. What is the pyrometer?

55. What remarkable exception is there to the general law that bodies are expanded by heat? Describe the experiment to show that water, in a particular case, is expanded by reducing the temperature.

after described, the experiment may be performed in a still more satisfactory manner.

56. The most important effects result from this remarkable property of water which has just been described. If the density of water continued to increase until it arrived at the freezing point, as is the case with mercury and other liquids, ice would be heavier than water, and as soon as formed would subside to the bottom in successive flakes, until the whole of the water, however deep, would become solid. The effects of such an arrangement can be easily conceived. Countries which, in the present state of things, are the delightful abodes of innumerable animated beings, would be rendered uninhabitable, and must inevitably become dreary and desolate wastes. But, since water expands previously to its freezing, as well as during this change, ice is lighter than water, and floats upon its surface, protecting the water, to some extent, from the further influence of frost.

#### DISTRIBUTION OF HEAT.

57. Heat is distributed in various ways; and we propose to discuss the subject under the heads of Conduction, Convection, Radiation, Reflection, and Transmission.

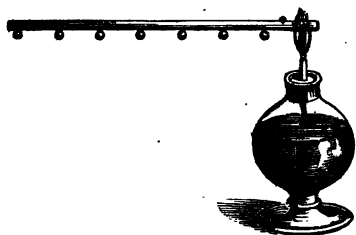
58. *Conduction of Heat.*—By this term is expressed the passage of heat from particle to particle, through the substance of bodies. Heat is said to be conducted by them, or to pass by *conduction*, and the property on which its transmission depends is termed their *conducting power*.

56. Do any important effects result from this peculiar property of water?

57. Under what heads are the phenomena attending the distribution of heat discussed?

58. What is meant by the conduction of heat?

59. The gradual passage of heat along a bar of metal is well shown by the following experiment:—Take a small



bar of copper, 18 or 20 inches in length, and cement to it several small bullets, or marbles, about two inches from each other, by means of wax, as shown in the figure, and then apply the heat of a lamp to one end.

As the heat progresses along the bar, it will melt the wax, and the balls will drop off in succession, the one nearest the lamp falling first, and the one farthest from it last.

60. If, on a cold morning of winter, the hand is placed successively upon a piece of metal, and then upon a piece of wood, the former will feel much colder than the latter, because the metal in equal times conveys away from the hand much more heat than the wood. Daily experience also teaches that we cannot leave one end of a rod of iron for some time in the fire, and then touch its other extremity without danger of being burned; yet, with a rod of glass, or wood, or charcoal, of but a few inches in length, it may be done with safety.

61. From these and other similar facts we learn that some substances conduct heat more rapidly than others: in some, as gold, silver, copper, and most of the metals, it passes rapidly; but in other substances, as glass, charcoal, porcelain, and very dry wood, it passes very slowly. Substances that conduct heat freely are called *conductors*, while those

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59. Describe the experiment showing the gradual progress of heat along a bar of metal.

60. Is the conducting power of different substances the same?

61. What are some of the best conducting substances mentioned? What non-conductors.

through which it passes slowly are said to be *non-conductors*.

62. There are, however, no absolute non-conductors; heat penetrates the substance of all bodies; the only difference in them, in this respect, is in the rapidity with which the process takes place. Gold is usually considered the best conducting substance known; and very porous solids, the interstices of which are filled with air, as cotton, or sheep's wool, and fur, are the poorest conductors.

63. Advantage is taken of the imperfect conducting powers of bodies, to prevent the passage of heat in any direction, particularly in confining it. Hence furnaces are generally lined with "fire-brick," or a thick coating of clay and sand. Wooden handles are fitted to metallic vessels, or a stratum of wood or ivory is interposed between the hot vessel and the metal handle. Ice-houses are constructed with double walls, which have their interstices filled with fine charcoal, saw-dust, or some other non-conducting substance, to prevent the influx of heat from without.

64. The design of clothing is to retain the heat produced by the system; and hence the warmest clothing will be that which possesses the least conducting power. In winter, the poorest conductors are selected, and in summer the best, as it is then desirable that the superfluous heat may be permitted at once to escape. If, in summer, the temperature of the atmosphere should rise considerably above that of the system, it would be found advantageous to use the same clothing as in cold weather, in order to prevent the accession of heat from without.

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62. Are there any real non-conductors?

63. What is the use of fire-brick in furnaces? How are ice-houses constructed?

64. What is the design of clothing? How does snow keep the earth warm in winter?



Snow, in consequence of its imperfect conducting power, serves as clothing to the earth in winter, and prevents its surface from being cooled down as low as it would otherwise be.

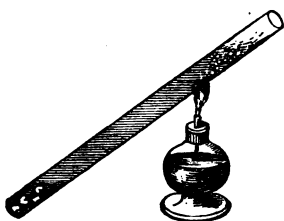
65. *Liquids* of all kinds are poor conductors of heat.



This may be shown by cementing a thermometer tube in a glass funnel, inverting it, and filling it with water, so as to cover the bulb about a quarter of an inch, or even less, as shown in the figure. Then pour upon the surface of the water a little sulphuric ether, and inflame it; the ether will burn brilliantly, but without affecting the thermometer for some time, although the flame is so very near the bulb.

In like manner, heated oil, poured upon the surface of water in a tumbler, can scarcely be made to affect a small thermometer placed at the bottom.

66. If a tube ten or twelve inches long be nearly filled



with water and placed in an inclined position, so that the heat of a spirit-lamp can be applied near the centre, the water in the upper part of the tube may be made to boil, while the lower portion will remain perfectly cold. If, before applying the

heat, a piece of ice be confined to the bottom, it will remain unmelted while the water above is boiling. Mercury, though liquid, is a very good conductor of heat.

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65. How may the poor conducting power of water be shown?

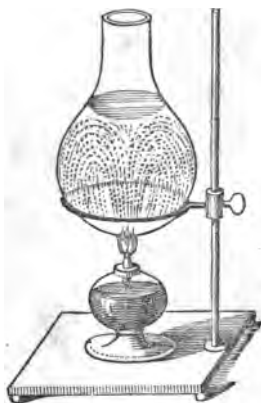
66. How by the use of a long tube?

67. The *gases* are even poorer conductors than liquids; and it is for this reason that very hot or very cold air can be endured in contact with a person, though exposure to a liquid of the same temperature would produce intense pain, or perhaps even worse effects. Double windows, as at Kensington Palace, England, and double doors, with air between them, are sometimes used to insure the greater warmth of dwellings.

68. *Convection of Heat.*—Though fluids are poor conductors of heat, yet, if the heat be applied to the bottom of the vessel containing them, in consequence of the mobility of their particles, it is rapidly diffused through the whole mass. The heated portions are expanded, and becoming, in consequence, specifically lighter than the rest, they rise through the centre of the vessel, the colder portions around the sides at the same time descending to take their place. Thus an upward and a downward current will be at the same time established, which will continue until the whole is heated to the boiling point. This mode of distribution is called the *convection* of heat.

These currents may readily be shown by filling a flask with water containing some insoluble powder, as pulverized gum copal, and applying the heat of a small lamp, as represented in the figure.

When large quantities of water are slowly heated, the upper por-



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67. What is said of the conducting power of gases?

68. In what mode is heat distributed through liquids? How may the currents produced be shown?

tions will frequently be found quite warm, while that in the lower part of the vessel will remain comparatively cold; and this though the fire is applied beneath. Hence it is not unfrequent, in bathing establishments, to draw both warm and cold water from the same reservoir.

69. Similar currents are produced in gases when heated; and it is on this account that the heated air, with the smoke and other gases from a fire, ascend in a chimney, or the pipe from a stove.

70. *Radiation of Heat*.—A hot body suspended in the air emits heat in all directions in right lines, like radii drawn from the centre to the surface of a sphere. This mode of distribution is termed the *radiation* of heat.

71. A heated body, as a cannon-ball, suspended in the air, will cool, or have its temperature reduced to an equality with that of the surrounding bodies, in three modes:—1. By the conducting power of the air; 2. By convection; and, 3. By radiation.

72. The radiation of heat from hot bodies is singularly influenced by the nature and condition of their surfaces, which is perhaps the most important circumstance connected with the subject. It is probable that every substance in nature has a radiating power peculiar to itself, but, in any case, very much will depend upon the nature of the surface of the body. By many experiments, it has been proved that bodies with bright polished surfaces retain their heat much longer than when their surfaces are rough and unpolished. Adding even a thin coat of whiting or lampblack to a bright tin vessel greatly increases the radiating power of its surface,

70. What is said of a heated body suspended in the air?

71. In what three modes will its temperature be reduced?

72. What is said of the surfaces of bodies, as affecting their power of radiating heat? What kind of surfaces radiate best? How will a coating of lampblack or whiting affect the radiating power of a body?

so that boiling water or other hot liquid contained in it will be cooled more rapidly in consequence. The same effect will be produced by scratching its surface with coarse sand-paper. So if a piece of fine linen or cotton cloth be wrapped around a bright metallic vessel filled with boiling water, contrary to what we might expect, its contents will be cooled by standing in the open air more rapidly than if it had been left entirely naked.

73. Some important practical considerations will naturally suggest themselves in connection with this subject. Whenever it is desired that the heat of a fluid or other substance should be retained, vessels with bright and polished metallic surfaces should be used, but the reverse if the heat is to be distributed. Thus tea and coffee pots are usually made of some bright metal, while stoves and stove-pipes, for the diffusion of heat, are made with dark and rough surfaces. Pipes to convey steam from the boilers in steam-engines to the cylinders, and pipes to convey heated air from furnaces to the different apartments of a building, should be bright, or else they should be protected by some non-conducting covering.

74. *Reflection of Heat.*—That heat may be reflected may be shown by standing at the side of a fire in such a position that the heat cannot reach the face directly, and then placing a plate of tinned iron opposite the grate, and at such an inclination as permits the observer to see in it the reflection of the fire; as soon as it is brought to this inclination, a distinct impression of heat will be produced upon the face.

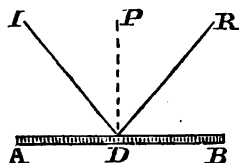
If a line be drawn from a radiating substance to the point of a plane surface by which its rays are reflected, and a

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73. What practical considerations are mentioned as resulting from these principles?

74. How may the reflection of heat be shown? Describe the angles of incidence and reflection.

second line from that point to the spot where its heating power is exerted, the angles which these lines form with a line perpendicular to the reflecting plane are called the angles of *incidence* and *reflection*, and are invariably equal to each other.



Thus, let AB (see figure) be the reflecting surface, and R a ray of heat, which strikes this surface at D, in the direction RD; it will be thrown off or reflected in the direction DI. If a perpendicular PD be erected at the point D, the angle RDP will be the angle of incidence, and IDP the angle of reflection.

These principles, which have just been developed concerning heat, apply as well to the invisible rays emitted from a moderately heated substance, as to those accompanied by light from an incandescent body, or the rays of the sun.

75. The absorption of heat by bodies sustains an intimate relation both to its radiation and reflection. Bright and polished surfaces, it is well known, are the best reflectors; and these are just the ones, we have seen (73), which radiate least. And rough, unpolished surfaces, which radiate heat best, are found to be the best absorbers.

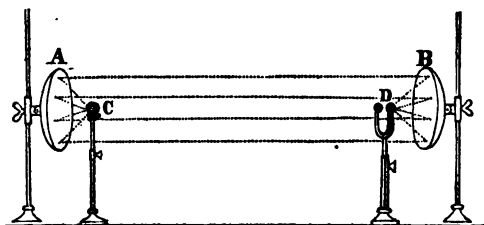
Surfaces may therefore be divided into two classes, those which afford an easy passage to heat, and those which do not. The former will be good radiators and absorbers, and the latter good reflectors and retainers.

Both the radiation and the reflection of heat are well shown by placing a heated cannon-ball in the focus of a

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75. What bodies absorb heat best? Into what two classes may surfaces be divided, in reference to their power of transmitting heat? Describe the experiment with the parabolic reflectors. What will be the effect if a lump of ice be substituted for the heated ball?

concave reflector, having another similar reflector facing it at a distance, in the focus of which is placed one of the



bulbs of a differential thermometer. The rays from the ball C are reflected in parallel lines from the reflector A (see figure), and are again concentrated on the thermometer D, by reflection from the second concave mirror B.

If a piece of phosphorus be substituted for the thermometer at D, it may often be inflamed, even when the reflectors are 10 or 20 feet distant from each other.

If a lump of ice is made use of, instead of the heated ball, the thermometer in the focus of the other reflector will fall; in which case the bulb of the thermometer is the radiating body, and its heat is received by the ice.

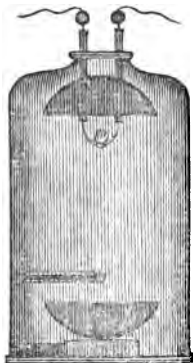
76. *Transmission of Heat.*—When a ray of heat impinges upon a body, it is plain that it must be disposed of in one of three modes:—1. It may rebound from its surface, or be *reflected*; 2. It may be received into the substance of the body, or be *absorbed*; or, 3. It must pass directly through it, or be *transmitted*.

77. In general, transparent substances afford the most ready transmission of heat, but there is a great difference among them in this respect. Even atmospheric air transmits

76. When a ray of heat impinges upon a body, in what three ways may it be disposed of?

77. Does the atmosphere affect the free passage of heat? Describe the experiment. What are diathermanous bodies?

heat but imperfectly. This is shown conclusively by an experiment of Davy. He contrived to heat a platinum wire by means of galvanism, within a receiver containing two concave reflectors, with a thermometer in the focus of one of them, the heated wire being in the focus of the other. Now, when the air was exhausted to  $\frac{1}{120}$ th part of its ordinary density, the thermometer, it was found, would be raised, by means of the ignited wire, three times as high as when the air in the receiver was at its natural pressure.



Bodies that transmit heat freely are said to be *diathermanous* (from the two Greek words, *dia*, through, and *thermos*, heat), as those which afford a free passage to light are said to be *transparent*.

78. By experiments made with a very delicate piece of apparatus, called the *thermo-multiplier*, it has been shown that the most diathermanous substance known is rock-salt, in pure transparent crystals. Of different specimens of glass, some are much more diathermanous than others, though all are equally transparent; and some colored glasses, and other bodies only partially transparent, afford a ready passage to heat, or are highly diathermanous.

79. It appears also that there are different kinds of heat, some kinds having the power of passing through diathermanous bodies more freely than others. In this respect, heat from an oil-lamp will differ from that of a spirit-lamp, though both are equally intense; and the heat of both will differ from that of heated metal.

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78. What is said of rock-salt in this connection? Are transparent bodies always diathermanous?

79. Is all heat of the same kind?

80. The rays of heat from the sun possess this power in a greater degree than any kind of artificial heat. Thus, a pane of window-glass, held between the face and a coal-fire, is found at once to intercept most of the heat; but no such effect is produced by holding it before the face when exposed to the direct solar ray.

The rays of heat, like those of light, may be refracted; and some of them being more refrangible than others, like the different colors of light, they may be separated from each other by means of the prism.—See *Decomposition of Light*.

#### RELATION OF HEAT TO CHANGES IN THE STATE OF BODIES.

81. We have seen above (12), that, omitting the imponderable agents, which are not known to be material, every substance must be in one of the three forms or states, solid, liquid, or gaseous; and that the particular form a body assumes will depend upon the relative intensity of the cohesive and repulsive forces existing among its particles.

If the repulsive force be comparatively feeble, the particles will adhere so firmly together, that they cannot move freely upon one another, thus constituting a solid (14). If cohesion is so far counteracted by repulsion that the particles move on each other freely, a liquid is formed (15); and, should the cohesive attraction be entirely overcome, so that the particles not only move freely on each other, but would, unless restrained by external pressure, separate from one

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80. What is said of the power of the sun's heat to pass through diathermanous bodies?

81. What three forms of matter are there? Upon what will the particular form or state a body assumes depend? When will a substance be solid? When liquid? When gaseous?



another to an indefinite extent, an aeriform substance will be produced (16).

82. Now, the property of repulsion is manifestly owing to heat; and as it is easy, within certain limits, to increase or diminish the quantity of this principle in any substance, it follows that the forms of bodies may be made to vary at pleasure: that is, by heat sufficiently intense, every solid may be converted into a liquid, and every liquid into vapor. The converse ought also to be true; and, accordingly, several of the gases have already been condensed into liquids by means of pressure, and the liquids have been solidified by cold. The temperature at which liquefaction takes place is called the *melting point*, or point of fusion; and that at which liquids solidify, their *freezing point*, or point of congelation. Both these points are different for different substances, but usually the same, under similar circumstances, in the same body.

83. *Liquefaction*.—By the liquefaction of a substance, we mean its reduction from either the solid or gaseous to the liquid state; but generally the former change is intended.

If, when the temperature of the air is at zero, as is often the case in some parts of our country, a quantity of ice be brought into a room, and placed near a fire, it will be gradually heated, like any other solid, as a thermometer placed in it will indicate, until the temperature reaches  $32^{\circ}$ ; but it will stand at this point until the whole is melted. The thermometer will then begin again to rise, as it did before. Now, it is plain that it must have been receiving heat as rapidly

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82. Upon what does the repulsive force depend? How may the form of many bodies be changed at pleasure? What is meant by the melting point? Freezing point?

83. What is meant by the liquefaction of a substance? Describe what will take place if a piece of ice be brought into a warm room from the open air, when the temperature is at zero. When is heat said to be latent?

while the thermometer was stationary, as before and afterwards; but the heat thus communicated did not affect the thermometer, because it was all absorbed by the ice, and was expended in changing the ice into water. It has therefore become insensible to the thermometer; and if heat were known to be material, we might perhaps, with some propriety, consider water as a compound of the solid, ice, and heat. Heat in this state is designated as *latent heat*.

84. The quantity of heat which is thus lost, or becomes insensible, during the melting of a mass of ice, is sufficient to raise the temperature of an equal weight of water about 140 degrees, as may be shown in the following manner:— Let a pound of water at  $32^{\circ}$  be mixed with a pound of water at  $172^{\circ}$ , and the temperature of the mixture will be intermediate between them, or  $102^{\circ}$ . But if a pound of water at  $172^{\circ}$  be added to a pound of ice at  $32^{\circ}$ , the ice will quickly dissolve, and on placing a thermometer in the mixture, it will be found to stand, not at  $102^{\circ}$ , but at  $32^{\circ}$ . In this experiment, the pound of hot water, which was originally at  $172^{\circ}$ , actually loses  $140^{\circ}$  of heat, all of which enters into the ice, and causes its liquefaction, without affecting its temperature.

The heat thus required for the liquefaction of solids is often called their *heat of fluidity*; and the quantity necessary for the purpose is not the same in any two substances. While the heat of fluidity of water is, as we have just seen,  $140^{\circ}$ , that of spermaceti is  $145^{\circ}$ , that of lead  $162^{\circ}$ , that of tin  $500^{\circ}$ , and that of bismuth  $550^{\circ}$ . That is, to melt any given weight of one of these substances, an amount of heat is required that would heat the same weight of the substance

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84. How many degrees of heat become latent when ice is melted? How is this shown? What is meant by heat of fluidity? Is the heat of fluidity the same in all substances?

the number of degrees indicated, provided no change of state should take place during the process.

5. The *melting point* of nearly all substances is the same as their freezing point; but this point varies greatly in different substances. Thus, solid mercury melts (and liquid mercury freezes) at  $-39^{\circ}$ ; ice at  $32^{\circ}$ ; spermaceti at  $132^{\circ}$ ; sulphur at  $226^{\circ}$ ; tin at  $442^{\circ}$ ; lead at  $612^{\circ}$ ; zinc at  $773^{\circ}$ ; silver at  $1873^{\circ}$ , and gold at  $2016^{\circ}$ .

86. *Freezing mixtures* are made of various salts and liquids, which have such an affinity for each other, that rapid liquefaction is produced, without the direct application of heat. But as this agent is always required when this change takes place, it must be absorbed from surrounding objects, which therefore lose their heat, or become cold. A good mixture of this kind is made of snow, or finely broken ice, and common salt, both of which, when mixed together, become rapidly liquid; and the process is attended with great cold, so that a thermometer immersed in it will fall to zero, or below. Of course, if a vessel of water be immersed in it, the water will in a short time be frozen.

Saltpetre, dissolved in cold spring water, will often reduce the temperature to  $32^{\circ}$ , or lower, so that water may be frozen by it; but the greatest cold is produced in this mode by mixtures of certain of the salts and acids. Directions for making them will be found in more extended works.

The greatest cold yet produced by means of freezing mixtures, is something less than 100 degrees below zero; but by means of solid carbonic acid, to be hereafter described, a

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85. Is the melting point the same in different substances? What is the melting point of mercury? Sulphur? Lead? Gold?

86. What are freezing mixtures? Is heat always required when solids are converted into liquids? What substances are mentioned as forming a good freezing mixture? What is the greatest cold produced by freezing mixtures? Is it possible to deprive bodies entirely of heat?

temperature has been attained as low as  $-175^{\circ}$ . Nothing, however, seems as yet to be determined concerning the absolute zero; nor is it supposed to be possible to deprive a body entirely of its heat.

87. Since solids, on becoming liquid, absorb heat, as we have seen, it necessarily follows, that when liquids become solid, heat must be given out. The freezing point of water is usually said to be  $32^{\circ}$ ; but if it be contained in a close vessel, and cooled very slowly without agitation, its temperature may be reduced, without freezing, to  $20^{\circ}$ , or lower. Slight agitation will now cause it to freeze suddenly, and the temperature will rise at once to  $32^{\circ}$ , the ordinary freezing point. The portion that has frozen, therefore, has given out sufficient heat to raise the temperature of the whole mass some 12 degrees. Saturated solutions of several of the salts, made at elevated temperatures, upon being slowly cooled, exhibit the same phenomenon.

A beautiful experiment may be performed by dissolving two or three parts of Glauber's salt in one part of hot water, and setting it aside in a closely corked phial till it cools. If now the cork is removed, or the vessel violently agitated, the salt will immediately crystalize, and a thermometer placed in it will rise several degrees.

We cannot but notice here the beautiful and unexpected manner by which nature, to some extent at least, checks the cold of winter, which might otherwise be destructive. The cold atmosphere causes large quantities of water to congeal, but at the same time heat is given out, which prevents so great a reduction of temperature as might, but for this circumstance, be experienced.

The peculiar mode provided by the Creator to check the

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87. How is it shown that water in freezing gives out heat? Describe the experiment with Glauber's salt.

heat of summer, which might otherwise become excessive, will be noticed hereafter.

88. *Vaporization*.—By this term is meant the conversion of liquids or solids into gases.

Aeriform bodies are often divided into vapors and gases, according to the relative force with which they resist condensation; but the distinction is of little consequence.

Heat is always required to convert a solid or liquid into a gas; usually, it is communicated directly, as when water is made to boil over a fire, but if not applied directly, it will always be absorbed from surrounding bodies.

In most cases, when heat is applied to solids, they first melt, or become liquid, and afterwards, by a continuance of the heat, are converted into vapor; but some, as metallic arsenic, and certain salts, pass at once, when heated, from the solid to the gaseous state.

89. Gases occupy considerably more space than the liquids from which they are formed. Water, when converted into steam, expands about 1700 times, so that a cubic inch of water forms nearly a cubic foot of steam; but most liquids expand much less than this. Alcohol, for instance, is expanded, when converted into vapor, only 659 times its original volume, and sulphuric ether 443 times.

*Volatile* substances are such as are readily converted into vapor by heat or at ordinary temperatures, while those that are incapable of this change are often called *fixed* substances.

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88. What is meant by vaporization? How are aeriform bodies sometimes divided? Is heat always required when a solid or liquid is converted into vapor? Do solids always melt before being converted into vapor, when heat is applied?

89. Do gases always occupy more space than the solids or liquids from which they are formed? How many times does water expand when it is converted into steam? When are substances said to be volatile?

90. When a liquid in an open vessel is exposed to any source of heat, the temperature gradually rises, like that of any other substance in similar circumstances, until a certain point is attained, when a violent motion commences in it, called *ebullition*, or *boiling*; and no heat can then cause any further increase of temperature. If the heat be continued, the quantity of liquid gradually diminishes, or, as we familiarly say, is boiled away, until the whole is gone. The commotion in the liquid is occasioned by portions of it at the bottom, where the heat is applied, being converted into vapor, and rising in bubbles to the surface.

Ordinarily it will be found that water boils at  $212^{\circ}$ , which is therefore called its *boiling point*; but the temperature at which other liquids boil is not necessarily the same, every liquid having a boiling point peculiar to itself. Thus, the boiling point of alcohol is only  $173^{\circ}$ , and that of sulphuric ether  $96^{\circ}$ , while that of sulphuric acid is  $620^{\circ}$ , and that of mercury  $662^{\circ}$ .

91. But the boiling point of a liquid is not by any means to be considered as perfectly constant; it depends upon several circumstances, the most important of which is the pressure of the atmosphere upon the surface of the liquid. By heating a small vessel of water to  $180^{\circ}$  or  $200^{\circ}$ , and placing it under the receiver of an air-pump, it begins to boil when the air is very moderately exhausted. So, on ascending a mountain, by which a part of the atmospheric pressure is avoided, the boiling point falls in proportion to the ascent.

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90. What are the circumstances that take place when a liquid is exposed to heat? What occasions the commotion which is seen in a liquid when it is boiling? At what temperature does water usually boil? What is the boiling point of alcohol? Sulphuric ether? Mercury?

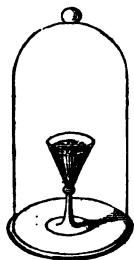
91. Is the boiling point of a liquid constant? What is the most important circumstance upon which the boiling point of a liquid depends? How is this shown in the case of water? What is the

At the hospital of St. Bernard, situated upon a point on the Alps, about 8400 feet above the sea, water boils at  $196^{\circ}$ .

This is just as we should expect, for the expansion of the vapor has to take place directly against the pressure of the atmosphere on the surface of the liquid; and the degree of heat necessary to produce the expansion will be to some extent proportional to the expansive force required.

The pressure of the atmosphere at the surface of the sea is usually about 15 pounds to each square inch, but it is subject to some variation; and the boiling point of any liquid will of course vary at the same time with the atmospheric pressure.

In a perfect vacuum, water boils at  $72^{\circ}$ , and sulphuric ether at  $-46^{\circ}$ , or about 140 degrees lower than in the open air.



As might be expected, sulphuric ether may easily be made to boil under an exhausted receiver, without heat, even in the coldest weather. For this purpose let a little good ether, in a wine-glass, be placed under an air-pump receiver, as represented in the figure; upon working the pump, it will boil violently. The experiment will usually succeed best if some small pieces of metal are dropped into the ether, before placing it under the receiver.

92. If water or other liquids boil at a lower temperature by diminishing the pressure upon the surface, so a higher temperature is required for this purpose when the pressure is increased, as in a steam boiler. Water cannot be heated

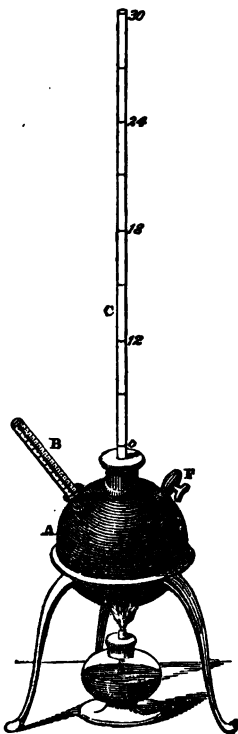
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boiling point of water at the hospital of St. Bernard, on the Alps? What is the ordinary pressure of the atmosphere, at the surface of the sea, upon each square inch of surface? At what temperature does water boil in a vacuum? How may ether be made to boil without heat?

92. How does increased pressure affect the boiling point of li-

above  $212^{\circ}$  in the open air, because any additional heat is expended in converting a portion of it into steam, which at once makes its escape into the air; but if it be confined in a strong vessel, it may be heated to any temperature, even to redness.

The rise of the boiling point under increasing pressure is well illustrated and proved by Marcet's steam apparatus, which is represented in the accompanying figure. A is a hollow brass globe, supported on a stand, and in it is contained a little mercury, and a small quantity of water. Through an air-tight collar, a graduated glass tube, C, is inserted, so as to reach very nearly to the bottom, both ends of it being open. B is a thermometer, having its bulb in the water or mercury. Now, by applying a lamp the water is heated, and when the temperature has risen to  $212^{\circ}$ , the steam will begin to issue freely through the faucet, F; but, by closing the faucet, the escape of the steam will be prevented, and the temperature will rise; the mercury at the same time, by the pressure of the steam within, being forced up the tube C, and the height to which it rises showing the exact amount of the pressure.—See the author's *Natural Philosophy*, p. 115.



By this means it has been determined that, at a heat of

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quids? Why cannot water be heated above  $212^{\circ}$  in the open air? Describe Marcet's steam apparatus. At what temperature would



250°, the tension of steam, thus confined in a boiler, is equal to two atmospheres, or 30 pounds to the square inch; at 275° its tension is equal to three atmospheres; and four atmospheres, or 60 pounds to the square inch, at 294°.

The expansive force of steam confined in this manner is the propelling power in the *steam engine*; for a description of which, see the author's work, above cited, p. 142.

Other circumstances which affect the boiling point of a liquid, are the nature of the vessel containing it, and the presence in it of any substance in solution. Water boils in metallic vessels at 212°, but in vessels of glass or porcelain, at about 214°. So, also, when even a small quantity of any salt is dissolved in it, the boiling point is sensibly raised.

93. But it is not only when a liquid is heated, and made to boil, that it is changed into vapor; this change, in most, and probably in all liquids, and many solids, is ever taking place, whatever may be their temperature, when they are contained in open vessels. This slow formation of vapor is termed *evaporation*. It is seen in the drying of clothes, when wet with water or alcohol, and in the gradual diminution of a quantity of either of these liquids, when left in an open vessel for a time.

Evaporation is much more rapid in some liquids than in others; and it is always found that those which have the lowest boiling point evaporate with the greatest rapidity. Thus, alcohol, which boils at a lower temperature than water, evaporates also more freely; and ether, whose point of ebullition is yet lower than that of alcohol, evaporates with still greater rapidity.

The chief circumstances that influence the process of water boil under a pressure of two atmospheres? What other circumstances affect the boiling point of liquids?

93. What is evaporation? What liquids evaporate with the greatest rapidity? What are the chief circumstances that influence evaporation?

evaporation, the extent of surface, and the state of the air as to temperature, dryness, stillness, and density. \

94. During the slow evaporation of water, or other liquids, as well as when they are evaporated by boiling, a large amount of heat is absorbed, and becomes latent in the steam produced. It is on this account that ether, alcohol, or even water, though at the same temperature as the air, always feels cold when a little is dropped upon the hand. The natural heat of the hand is absorbed and carried off in the vapor that is formed.

The evaporation of good sulphuric ether may easily be made to freeze water, even in the warmest weather. For this purpose let a very small glass vial, covered with muslin, be filled with water, and suspended by the neck from some convenient support; then drop slowly upon the muslin good sulphuric ether, from the mouth of a vial. In a few minutes, ice will begin to form; and if the operation be continued, the whole of the water will be frozen, perhaps breaking the vial containing it.

So, if a small vial of water be placed in a vessel of ether, which is made to boil under an exhausted receiver (91), it will in a short time be frozen by the cold produced by the evaporation of the ether. Indeed, a small drop of water may be frozen under the receiver of an air-pump by its own evaporation. Let a single drop of water, on a piece of charred cork, hollowed a little on its upper surface, be placed under the air-pump receiver, and by working the pump a few seconds, it will be frozen by the rapid evaporation which takes place from its surface. The burnt cork capsule is preferable to one of glass or metal, since, as the water does not adhere to its surface, not so much heat is received from it.

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94. Is heat absorbed during the slow evaporation of liquids? How is this shown? How may water be frozen by the evaporation of ether? How may a small drop of water be frozen by its own evaporation?

95. By various methods, it has been very well determined that about  $1000^{\circ}$  of heat are absorbed by water as it becomes vapor; that is, heat enough to raise the temperature of an equal quantity of water  $1000^{\circ}$ , if it were possible to confine it. The amount of latent heat in each vapor is peculiar to itself, that of vapor of water being, as we have seen,  $1000^{\circ}$ , while that of vapor of alcohol is  $42^{\circ}$ , that of vapor of ether  $302^{\circ}$ , and of oil of turpentine  $178^{\circ}$ .

The heat which is absorbed when water or other liquid is converted into vapor, will, as a matter of course, be given out again when this vapor is condensed into the liquid form. On this principle, steam is often used for warming buildings, being conveyed in pipes through the different apartments. As it passes along the pipes, it is condensed, giving out its heat; and the water that is formed runs back again into the boiler.

96. The process of *distillation* consists simply in evaporating a substance, and again condensing the vapor, by causing it to come in contact with a cold surface. This is usually accomplished by having a tube of considerable length, leading from the top of a close boiler, and passing in the form of a spiral through a vessel which is kept filled with cold water.

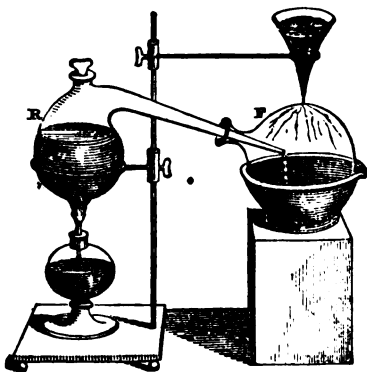
In the laboratory, the apparatus figured at the top of the opposite page, answers well for distilling small quantities of any liquid. A retort, R, contains the liquid to be distilled, and the vapor is received into a flask, F, the mouth of

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95. How many degrees of heat are absorbed when water is converted into vapor? What is the amount of latent heat in vapor of alcohol? Will the latent heat of vapor be given out when it is condensed to the liquid state? How is steam used to warm buildings?

96. In what does the process of distillation consist? Explain why it is that alcohol is separated from water by the process of distillation.

which is slipped on the neck of the retort, but the joint not made perfectly air-tight. — The flask should be kept cold by being immersed in cold water, or by having a small stream of water constantly falling upon it from a vessel above. By this process, volatile substances, whether li-



quid or solid, may be separated from those that are fixed, or even from such as are less volatile than themselves. Water is distilled to purify it from salts or other substances it may contain in solution or suspension; and alcohol, by distillation, is separated from water, which is less volatile than itself, as well as from fixed substances.

The application of this process to solids is usually termed their (*sublimation*.)

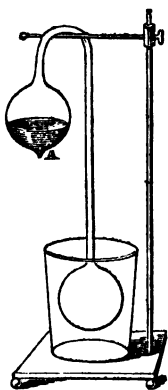
97. We have seen above (91) the effects of diminishing or removing the atmospheric pressure in promoting ebullition, and we are now prepared to understand another ingenious method of accomplishing this object. Let a flask, with a cork well fitted to its mouth, be partly filled with water, and made to boil briskly by means of a spirit-lamp; then suddenly insert the cork and remove the lamp: the water will con-



97. Describe the method of causing water to boil by the use of snow. Why does the application of heat stop the boiling?

tinue to boil, and by immersing it in cold water, as shown in the figure, the boiling will become violent. The same effect will be produced by inverting the flask and applying snow or even cold water to the bottom. But if the flask be held again a moment over the lamp, the boiling will instantly cease. The reason of this is, because the upper part of the flask, when the cork is inserted, is filled with steam, which is condensed by the application of cold to the outside, and a vacuum produced. The warm water within then boils, as in a vacuum produced by any other means; but if heat be applied, steam will be again formed, and fill the upper part of the flask, and, by its pressure upon the surface of the water, prevent further boiling.

98. The *cryophorus*, or *frost-bearer* (from the two Greek words, *cruos*, frost, and *phero*, I bear) is an instrument for freezing water by its own evaporation, which beautifully illustrates some of the foregoing principles. It consists of a tube, half an inch or more in diameter, with a bulb blown at each end, one of them having a small aperture, A, by which a small quantity of water is introduced, sufficient only partly to fill one of the bulbs. This water is first all collected in the lower bulb, and the heat of a lamp applied, so as to cause it to boil briskly; and while the interior is filled with steam, the aperture at A is quickly sealed hermetically, and the lamp removed. When it has become cold, the water is passed to the upper bulb, as represented in the figure, and the instrument supported on a stand, with the lower bulb in a large tumbler. All the interior is now filled



98. Describe the cryophorus. How is the water in it frozen? Describe the pulse-glass.

with vapor of water, except a part of the upper bulb, but no evaporation of the water can take place, because of the presence of this vapor. But by removing the vapor, which is accomplished by surrounding the lower bulb with a freezing mixture of salt and snow, to condense it rapidly, evaporation of the water is produced, attended with cold sufficient to freeze the most of it, even in the warmest weather.

The *pulse-glass*, as it is called, is a very similar instrument, and is made in the same manner, except that ether is used in it,



instead of water. By grasping one of the bulbs firmly in the hand, the vapor, by its expansion, will immediately force all the liquid into the other; and the moment it has all passed through the stem, an appearance of violent ebullition is produced, attended by a distinct sensation of cold in the hand which grasps the bulb. This is occasioned by the rapid evaporation of the film of liquid lining the inside of the bulb.

99. The effect of evaporation in withdrawing heat is admirably illustrated by the process of perspiration. The natural temperature of the human body is about  $98^{\circ}$ , but when we take active exercise, or when we are exposed to a great degree of heat, there is a tendency to a rise of temperature above that which is conducive to health; and the most injurious effects would ensue, if they were not prevented by the rapid evaporation which takes place from all parts of the surface of the system.

Examples of the power of the human body to sustain great and apparently even dangerous elevations of temperature, are on record. It is well known that individuals have voluntarily exposed themselves for several minutes, in ovens, to temperatures even a hundred degrees above that of boiling

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99. How does perspiration prevent the too great rise of temperature in the system in warm weather, or during active exercise?

water, without suffering any injury. The very rapid perspiration that takes place in such circumstances, prevents the destructive elevation of temperature in the system which would otherwise take place.

In the same manner the high temperature of summer is mitigated by the evaporation of water from the surface of the earth.

We have seen above (87) that heat given out by the freezing of water in winter, prevents the low reduction of temperature that would otherwise be experienced; and we cannot here less admire the wonderful provision of Providence, by which, on the other hand, the excessive heat of summer is, to some extent, limited.

Porous earthen vessels are often used in hotels and other places, in warm weather, to contain water for drinking. A portion of the water gradually exudes through the vessels, and evaporates from the surface, by which that within is kept several degrees colder than the temperature of the atmosphere. Such vessels are said to be much used in Spain, where they are called *alcarrazas*. People crossing the deserts of Arabia in caravans, are said sometimes to load camels with earthenware bottles filled with water, which is kept cool by wrapping the jars with linen cloths, and keeping them moist with water.

100. *Dew* is a deposite of moisture from the atmosphere upon a cold surface in contact with it. If, in the summer, a vessel is left but a few minutes filled with ice-water, or even cold spring-water, dew soon collects upon it, and after a time, the water thus condensed trickles down the surface in drops. A surface upon which dew is seen to form will

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What means has nature provided to mitigate the excessive heat of summer? Why are porous vessels sometimes used for containing drinking water?

100. What is dew? Why does dew form on the outside of vessels containing cold water? What is meant by the dew-point?

always be found colder than the surrounding air; and the particular temperature at which it begins to form is called the *dew-point*. When the air is very dry, this point will always be considerably below the temperature of the air; but when there is much moisture present this will not be the case.

In fair weather, during the summer season, there is usually seen, in the morning, a copious deposit of dew upon the leaves of plants, and upon other substances exposed to the open air. This is occasioned by the radiation of heat from bodies at the surface of the earth, which takes place rapidly during the night, cooling them down considerably below the temperature of the air. Substances, therefore, which radiate slowly (72), as polished metallic surfaces, seldom have any dew upon them, while good radiating surfaces near them will be abundantly covered with it.

In cloudy weather (without rain), there is generally little dew, because the heat radiated from the earth is reflected back by the clouds; and by suspending even a small handkerchief by the four corners, a few inches from the earth, the deposition of dew on substances under it is for the same reason, prevented.

In some warm countries, water is said to be frozen during the night by the rapid radiation which takes place from its surface. The water for this purpose is poured into shallow pans, so situated as to receive as little heat as possible from the earth.

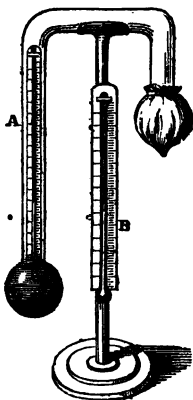
101. *Hygrometers*, of which there are several, are instru-

By what means do the surface of the earth, and of bodies upon it, become so cooled during the night in summer, as to receive a deposit of dew? What substances are most likely to be coated with dew, when exposed to the air during the night in summer? Why in cloudy weather is there little or no dew? How is water frozen in some warm countries?

101. What are hygrometers? Describe Daniel's hygrometer.



ments for determining the relative quantities of moisture in the air, at different times or in different places. Daniel's



hygrometer, which is preferred before all others, is represented in the drawing in the margin. It consists of a tube, A, with a bulb at each end, and is formed in the same manner as the cryophorus (98), except that it contains ether instead of water. The tube is supported by a stand; and the lower bulb, which is usually made of colored glass, is about half-filled with the ether, having in it the bulb of a very delicate thermometer, with its stem extending upward in the tube. The other bulb is empty, or containing only the vapor of ether, and is covered with

muslin. To the stand B is attached a small thermometer, to indicate the temperature of the air. By pouring a little ether upon the muslin, the bulb is cooled, and the vapor of ether within condensed, and a rapid evaporation of the ether in the other bulb produced, as in the cryophorus. This occasions a cooling of the colored bulb, and a deposition of dew upon its surface, the small thermometer within showing the exact temperature at which the process commences, which is taken as the dew-point. Properly, however, it is the difference between the temperature thus obtained, and the temperature of the air, which shows the real state of the air as to moisture.

102. Watery vapor, when it rises in the atmosphere, is perfectly invisible; but in certain circumstances, which do not seem to be well understood, it becomes visible, constituting mists and clouds, which are constantly seen floating

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102. What are clouds? What is rain? Whence comes the water that falls in rain and snow?

in the air. This moisture, after remaining a while suspended in the air, is again condensed, and descends to the earth in the form of rain. Rain, it is well known, never falls unless the sky is cloudy, nor unless that peculiar kind of dense black cloud appear, known by the name of *rain-cloud*; but the manner in which rain is formed, though different theories have been proposed to account for it, must yet be considered as involved in obscurity.

All the water upon the surface of the earth is in this manner subjected to a constant natural distillation; pure water, in the form of vapor, rises in the air from the leaves of plants, from the earth, and from the surface of the ocean, rivers, and lakes, to be again diffused, in rain and snow, over the earth, producing everywhere vigor and life, both in the vegetable and animal world.

103. *Constitution of the Gases in respect to Heat.*—The gases, or many of them, are capable of being reduced to the liquid state by the combined influence of cold and pressure, which seems to justify the opinion that they are all merely (the vapors of extremely volatile liquids.)

In order to liquefy a gas, the materials to form it may be put in a tube of glass, bent as in the



figure, and kept separate, if necessary, until the tube is hermetically sealed; they are then brought together by reversing the position of the tube, and the gas is liberated by the chemical action which ensues. The pressure increases until a certain point is attained, depending upon the temperature and the nature of the gas, when it begins to collect in the liquid form. Heat may be applied, if necessary, to the end

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103. What may we consider the gases? Describe the usual method of liquefying a gas. Are all the gases liquefied by the same compressing force?

of the tube containing the materials, or a freezing mixture to the other, to condense the gas.

Different gases require very different forces to compress them into liquids; thus, sulphurous acid gas, at the temperature of  $32^{\circ}$ , takes the liquid form under a pressure of 2 atmospheres; while carbonic acid gas, at the same temperature, requires a pressure of 36 atmospheres, according to some experimenters, or about 27 atmospheres, according to others. The pressure required is much greater at high than at low temperatures.

104. The liquids formed from the gases, in the manner described (may be frozen) by the great cold produced by their own evaporation, or by exposing them in tubes to intense cold. In the former case, the solids formed will appear like snow, and in the latter, like clear, transparent ice.

The solidification of carbonic acid gas is now of common occurrence in the laboratory of the chemist; but a very strong and somewhat expensive apparatus is required for it, the full description of which would occupy too much space to be here inserted. The materials for forming the gas are introduced into a strong iron vessel, called the generator, capable of resisting great pressure, so that when the gas is formed, it is compressed into a liquid, which is afterwards distilled into another strong iron vessel, called the receiver. From the receiver, the liquid, when every thing is ready, is allowed to escape in a very small jet, and is received into a cup, so contrived as to retain the solid as it is formed. When the liquid is received in the cup, it hisses and boils with the greatest violence; and the cold produced (by the evaporation of a part of it is so great as to freeze the rest,) (which is retained in the cup as a fine white snow.) By roll-

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104. May the liquids thus formed be frozen? Describe the mode of solidifying carbonic acid. How is the cold produced that freezes the liquid? What is the appearance of the solid as

ing this in balls, and wrapping it in cotton, it may be kept some time; but in the open air it evaporates rapidly, and intense cold is produced, equal, it is said, to  $-148^{\circ}$ ; although the author has not been able, by this means, to obtain a lower temperature than about  $(-110^{\circ})$ . By moistening the solid with ether, and placing it in an exhausted receiver, it is claimed that a temperature as low as  $175^{\circ}$  or  $180^{\circ}$  below zero has been produced.

Mercury, which congeals at  $-40^{\circ}$ , is of course easily frozen by mixing it with this substance. In this state it much resembles lead, but is softer, and is more easily hammered or cut with a knife.

#### SPECIFIC HEAT.—CAPACITY OF BODIES FOR HEAT.

105. The *specific heat* of any substance, is the quantity of heat required to raise its temperature any given number of degrees, as compared with that required to produce a like effect upon some other substance, adopted as a standard.

106. When a body is exposed to any source of heat, its temperature rises, and the substance of heat is supposed to accumulate in it; but the same quantity of heat, imparted to different bodies, will not raise their temperature alike. Thus, if a pound of water and a pound of mercury, in similar vessels, and at the same temperature, be exposed to the same source of heat, the temperature of the mercury will rise  $30^{\circ}$  while that of the water rises only  $1^{\circ}$ . It appears, therefore, that it requires 30 times as much heat to raise the tempera-

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thus formed? How low a temperature may be produced by the use of this substance?

105. What is the specific heat of a substance?

106. Will the same quantity of heat raise the temperature of different substances equally? How is this point illustrated by the use of water and mercury? To heat water and mercury equally, what proportional quantities of heat are required? Has every

ture of water any given amount, as it does to produce the same effect upon mercury. This idea is expressed by saying that the specific heats of these substances are as 30 to 1; or we say (as some prefer) that the *capacity for heat* of water is to that of mercury as 30 to 1. (By some experimenters it is said to be as 23 to 1.)

The same principle applies to all other substances, as well as to mercury and water; every substance has a specific heat peculiar to itself.

Other methods of determining the specific heat of bodies have been devised, one or two examples of which will be given. If a pound of olive-oil and a pound of water be heated to some given temperature, say  $80^{\circ}$ , and then placed in a cold room, and the number of minutes noted which is required for each to cool an equal number of degrees, say to  $50^{\circ}$ , it will be found that the oil will cool in less than half the time required by the water; but as both substances must be supposed to lose equal quantities of heat in equal times, it follows that the water must have contained more than twice as much as the oil; or the capacity of water for heat is more than twice that of this oil. If a piece of copper, of a pound weight, be heated to  $300^{\circ}$ , by holding it a few minutes in mercury at this temperature, and then immersed in a pound of water at  $50^{\circ}$ , the copper will give out heat to the water until the temperature of both will be at  $72^{\circ}$ . Now, the copper has lost 228 degrees of heat, and the water has acquired 22 degrees. The specific heat of water, therefore, is to that of copper as 228 to 22.

It is usual to make water the standard in comparing the specific heats of bodies, considering its specific heat as 1.000; we shall then have the specific heat of mercury  $1 \cdot \frac{22}{30} = .033$ , and that of copper  $\frac{22}{228} = .096$ .

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substance a specific heat peculiar to itself? Describe the experiment with olive-oil and water. What substance is usually made the standard with which to compare the specific heats of bodies?

The specific heat of the gases is usually compared with that of air, taken as 1.000.

The following table exhibits the specific heats of several well-known substances :—

|              |       |               |       |
|--------------|-------|---------------|-------|
| Water.....   | 1.000 | Gold .....    | 0.032 |
| Iron.....    | 0.114 | Silver .....  | 0.057 |
| Copper ..... | 0.096 | Alcohol.....  | 0.660 |
| Lead .....   | 0.031 | Tin .....     | 0.056 |
| Sulphur..... | 0.203 | Platinum..... | 0.032 |

107. In general, the specific heat of a body sustains an intimate relation to its density, it being greater as the density is less. Thus, by hammering a piece of metal smartly, its density is increased, and it will often become red-hot; so, by mixing equal measures of sulphuric acid and water, considerable condensation takes place, attended by great heat.)

108. This principle is beautifully illustrated by the *fire-syringe*, an instrument which consists merely of a tube with an equal straight bore, and a solid piston fitted to it very accurately. When the piston is plunged forcibly into the tube, the air is much condensed before it, by which its temperature is raised, in consequence of its specific heat being diminished; and if a little tinder or other highly combustible substance has been previously attached to the lower side of the piston, it will be ignited.



On the other hand, if the density of a body be diminished, the capacity for heat is increased, and cold is

107. Why does a piece of metal become hot by hammering? Why does sulphuric acid become very warm when mixed with water?

108. Describe the fire-syringe. What use is made of it? How is the capacity of a body affected if its density is diminished? Why does a thermometer, placed under the receiver of an air-pump show a fall of temperature when the air is exhausted? How is the fact to be explained, that the hand may be held in a jet of steam from a high-pressure boiler?

produced. A thermometer placed under the receiver of an air-pump, falls as the air is exhausted.

When steam from a high-pressure boiler is allowed to escape in the air, it is cooled by the sudden expansion which takes place, so that the hand may be held in it with safety.

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## LIGHT.

### NATURE AND SOURCES OF LIGHT.

109. *Nature of Light.*—Although innumerable observations and experiments have been made upon light, yet it must be admitted that some doubt and obscurity still remain concerning its real nature. But, in the absence of positive knowledge, two theories of light have been proposed, by each of which nearly all the phenomena attending it may be satisfactorily explained; and it is admitted that each is also attended with its peculiar difficulties. These are called the *Newtonian*, or *corpuscular*, and the *undulatory* theories.

110. The Newtonian theory supposes light to be material, and to consist of inconceivably minute particles, which, however, are too subtile to exhibit the common properties of matter. These particles, emanating from luminous bodies, such as the sun, the fixed stars, and incandescent substances, and traveling with immense velocity, excite the sensation of light, it is supposed, by passing bodily through the substance of the eye, and striking against the expanded nerve of vision, the retina. The whole language of optics is founded on this theory.

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109. Is the real nature of light fully understood? What two theories of light have been proposed?

110. Describe the Newtonian theory.

111. The undulatory theory, which is now generally adopted, denies to light a separate material existence, and ascribes its effects to the vibrations or undulations of a subtile ethereal medium, supposed to be universally present in nature, the pulses of which, in some way excited by luminous objects, pass through space and transparent bodies, and give rise to vision by impressing the retina, in the same way as pulsations of air impress the nerve of hearing, to produce the sensation of sound.—(See *Natural Philosophy*, p. 15.)

112. Light is not a homogeneous substance, as might be supposed, but the white light of the sun is made up of rays of several different colors, as will be shown when we come to speak of its decomposition, or analysis. So, also, it is capable of producing several distinct classes of effects, which have been attributed to the action of distinct agents; as the colorific rays, or the rays which produce the phenomena of color, the heating rays, and the chemical rays, or those which are capable of producing chemical changes. Thus it is possible, by causing the solar ray to pass through certain substances, to separate the heat entirely from it; or its illuminating power may be destroyed, and a distinct, invisible ray of heat be obtained. So, also, chemical effects may be produced by rays which seem to be destitute of any heating or illuminating power.

113. *Sources of Light.*—The sun is the great source of light to the earth, and all things upon its surface. As rays of heat always accompany the light of the sun, it is natural to suppose that the sun is an intensely heated mass, which is constantly throwing off both light and heat in every direc-

111. Describe the undulatory theory.

112. Is light homogeneous? Of what is the white light of the sun composed? What distinct classes of effects are mentioned as produced by light? May the light and heat of the solar ray be separated?

113. What is the great source of light to the earth?



tion, like a red-hot cannon-ball suspended in the air; but this cannot be proved. At the present day, it is generally believed that the body of the sun is a dark, opaque substance, surrounded by luminous clouds, unlike any thing, perhaps, with which we are acquainted upon the earth, but which are the real source of the sun's rays. These clouds are supposed to be of great thickness; but occasionally they break away in places, showing the body of the sun beneath them, which constitute the spots often seen upon his surface.

The great distance of the sun from the earth—95,000,000 of miles—very probably will ever prevent us from knowing more with certainty of his real nature.

114. *Artificial light* is produced by various modes, but chiefly by combustion, by the burning of a lamp or candle, or a mass of charcoal; but it may also be produced by galvanism,—in a manner to be hereafter explained,—by decaying animal and vegetable substances, called *phosphori*, and by every means which produce great heat.

All bodies begin to emit light when heat is accumulated within them in great quantity; and the appearance of glowing or shining, which they then assume, is called *incandescence*. The temperature at which solids in general begin to shine in the dark, is between  $600^{\circ}$  and  $700^{\circ}$ ; but they do not appear luminous in broad daylight till they are heated to about  $1000^{\circ}$ . The color of incandescent bodies varies with the intensity of the heat. The first degree of luminousness is an obscure red. As the heat augments, the redness becomes more and more vivid, till at last it acquires a full red glow. If the temperature still increase, the character of the glow changes, and by degrees it becomes white, shining

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114. How is artificial light produced? May light be produced by other means? At what temperature does a body become incandescent in daylight? Do lights differ in color? Is the chemical agency of artificial light the same as that of the solar ray?

with increasing brilliancy as the heat augments. Liquids and gases likewise become incandescent when strongly heated; but a very high temperature is required to render a gas luminous, more than is sufficient for heating a solid body even to whiteness. The different kinds of flame, as that of a wood-fire, candles, and gas-lights, are instances of incandescent gaseous matter.

Artificial lights differ greatly in color, some being of a brilliant white, and others being red, blue, yellow, or green. The chemical agency of artificial light is in general analogous to that from the sun; but in most cases it is too feeble to produce very decided effects.

115. Many substances have the power of emitting a feeble light, unattended by sensible heat, and are called *phosphori* (from two Greek words, *phos*, light, and *phero*, I bear). Certain living animals also possess the same property, as the glow-worm, and the common fire-fly. This property of bodies is termed their *phosphorescence*.

Some phosphori, as that prepared by mixing sulphur and oyster-shells, and exposing the mixture for a time to a strong heat, the diamond, fluor-spar, &c., shine only after having been heated, or exposed for a few moments to a strong light; while others, as moist, decaying wood, and decaying fish, shine without such preparation, even at ordinary temperatures.

#### DISTRIBUTION OF LIGHT.

116. Light emanates from every point in the surface of a luminous body, and is equally distributed on all sides, if not intercepted, diverging like radii drawn from the centre to the

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115. What are phosphori? Are living animals sometimes phosphorescent?

116. What is the course of a ray of light when uninterrupted?

surface of a sphere. Thus, if a single luminous point were placed in the centre of a hollow sphere, every point of its concavity would be illuminated, and equal areas would receive equal quantities of light. Each ray, when not interrupted in its course, and while it remains in the same medium, moves in a straight line, as is obvious by the appearance of shadows cast by the side of a house, or of a sun-beam admitted through a small aperture into a dark room. Owing to these modes of distribution, it follows that the quantity of light which falls upon a given surface decreases as the square of its distance from the luminous object increases—the same law which regulates the heating power of a hot body.

117. The passage of light is progressive, time being required for its motion from one place to another. By astronomical observations it is found that light travels at the rate of 195,000 miles in a second of time, and requires about eight minutes to pass from the sun to the earth. Owing to this prodigious velocity, the light caused by the firing of a cannon or a sky-rocket is seen by different spectators at the same instant, whatever may be their respective distances from the rocket, the time required for light to travel 100 or 1000 miles being inappreciable to our senses.

118. *Reflection of Light.*—Light is reflected in the same manner as heat (74), obeying precisely the same laws. This always takes place when it passes from one medium into another of different nature or density, whether the media be solid, liquid, or gaseous. Different media, however, differ much in their power of reflection.

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What is the law of the distribution of light at different distances from the luminous body?

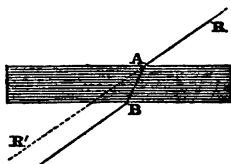
117. Is the passage of light instantaneous or progressive? What is its velocity? How long is it in coming to the earth from the sun?

118. When is light said to be reflected? What is the law with regard to the reflection of light as well as heat? What are the best reflecting surfaces?

Bright metallic surfaces, as polished silver or clean mercury, reflect nearly all the rays which fall upon them; while those which are dull and rough reflect but a few. The reflection of light, like that of heat, takes place at the surface of bodies, and appears to be influenced rather by the condition of the surface than by the internal nature or structure of the reflecting body.

119. *Refraction of Light.*—When a ray of light passes through the same medium, as glass or water, or when it passes perpendicularly from one transparent medium to another, it moves in perfectly straight lines; but when it passes *obliquely* from one medium into another of different density, it is thrown more or less out of its first direction, and is said to be *refracted*.

Thus, a ray of light, R, passing through the air, when it comes in contact with a piece of polished glass at A, does not move on in a straight line to R', but is bent downward or refracted, and emerges from the glass at B, where it is again refracted in the opposite direction, and takes the same course, though not precisely the same path, as it had at first.



Refraction always takes place when a ray of light passes obliquely from one medium to another of different density, but not always to the same amount; this will depend upon the *refracting power* of the two media, and also upon the obliquity of the ray to the surfaces of the media in contact.

When the ray passes from a rare to a dense medium, it is always refracted or bent *towards* a line perpendicular to the surface at the point of contact, and *from* this line when it

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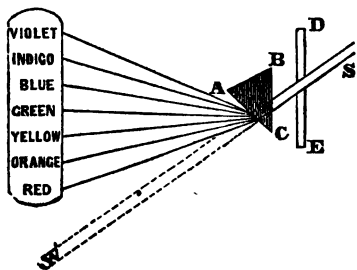
119. Under what circumstances is light refracted? Explain the figure connected with this paragraph. Do all bodies of equal density refract light equally? When the ray passes from a rare to a

passes in the opposite direction, from a dense to a rare medium.—(For a fuller explanation of this interesting subject, see *Natural Philosophy*, p. 183.)

By means of the reflection and refraction of light, in different modes, images of objects may be formed in a variety of ways; but the discussion of the subject would be out of place here.

### DECOMPOSITION OF LIGHT.

120. The white light of the sun is not a homogeneous substance, but is capable (112) of being separated into several rays of entirely different colors. This was first effected by Newton, by passing it through a triangular piece of clear, solid glass, called a *prism*.



In the figure in the margin, let S be a ray of light from the sun, admitted into a darkened room through the window-shutter, DE; it will pass downward to the floor, at a little distance from the wall, producing a circular

spot of clear white light, W. Then let the prism ABC be held in the ray, and at once the spot at W will disappear, and, in its stead, an elongated and beautifully colored image of the sun will be seen upon a screen hung up in front of the window, or on the wall at the opposite side of

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dense medium, in what direction is it refracted? When it passes from a dense to a rare medium?

120. How may the different colors of light be separated? Explain the mode of separating the different colors, as illustrated by

the room, if no screen be used. The several colors will appear in the order indicated, the violet being uppermost and the red lowest.

It will be seen that the light, in passing the prism, has been twice refracted, or bent upward, first as it entered the glass, and again as it issued from it; and that the separation of the several colors has been in consequence of their different refrangibilities. The violet, being most refrangible, is found uppermost in the picture, and the red is lowest, because least refrangible. The other colors occupy intermediate positions, depending upon their respective refrangibilities.

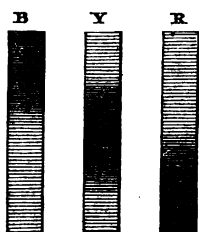
The colored image thus produced is called the *solar spectrum*; and, according to Newton, it is composed of the seven colors named in the figure, which are therefore called *primary colors*.

121. More recent investigations by Brewster render it probable that there are in the spectrum really only three colors, red, yellow, and blue, and that the other shades are produced by mixtures of these in different proportions; a mixture of the blue and the yellow, for instance, producing the green, and a like mixture of the red and yellow producing the orange. Indeed, it is believed that each of these three colors extends over the whole spectrum, but each is much more intense at one part of the spectrum than elsewhere, the blue being most intense near the top, and the red near the bottom, with the most intense portion of the yellow between them. The solar spectrum, therefore, as produced by the prism, may be considered as composed of three simple spectra superimposed upon each other.

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the figure in the margin. What is the colored image of the sun produced called? What are these seven colors called?

121. How many primary colors are there, according to Brewster?



The distribution of the rays in each of these simple spectra is represented by the shading of the annexed figures.

It has been stated above (112) that light is capable of producing several distinct classes of effects, as those of color, those of heat, and besides these, others which may strictly be called chemical effects. Now, these several

effects are not produced in every part of the spectrum with equal facility; the greatest illuminating power is found to be in the yellow, while the greatest heat is in the red, or a little below it, and the greatest chemical effects are produced in the extreme violet.

122. The chemical effects of light are various and important; a mixture of chlorine and hydrogen gases may be kept together in the dark for any length of time, without combining, but unite with an explosion when placed in the direct sunlight. On the other hand, many compound substances are decomposed by light, as certain preparations of gold and silver. If a piece of white paper be coated over with a thin film of white chloride of silver, carefully prepared in the dark, and then placed in the solar spectrum, the part in the violet ray will soon become black, while that in the red will scarcely be affected. Between these extremes there will be produced various shades of gray and purple.

The light of the sun produces most important effects in the vegetable world; many plants will not grow in the dark, and others growing in the shade have their nature entirely changed.

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In what part of the spectrum is the greatest illuminating power? In what part are the chemical effects greatest?

122. What are some of the chemical effects of light? Is light of any importance to vegetation?

123. *Photography*.—By this name we designate the various modes of producing pictures by the action of light. If a piece of white paper is moistened with a dilute solution of common salt, and then one side of it washed with a solution of nitrate of silver, the surface becomes coated with coloride of silver, which readily turns black or dark chestnut by exposure to the direct rays of the sun. If, now, before exposing paper thus prepared to the light, any small flat object, as a flower, or piece of lace, be placed upon it, an image of the object will remain upon the paper, and may be rendered permanent by soaking it *immediately* in a saturated solution of common salt, or of iodide of potassium.

Instead of these substances, numerous others may be used, and pictures formed with peculiar characteristics, depending upon the nature of the process adopted. The light produces a chemical change in the parts of the picture exposed to its influence, and the picture is *fixed* by soaking the paper in a solution capable of dissolving out the sensitive substance contained in the parts which have not undergone this change, in consequence of being in the shade.

*Photogenic paper*, as paper prepared for taking impressions in any of these modes is called, must of course be preserved in the dark; and even then it is extremely liable to spontaneous change, which renders it unfit for use.

124. Daguerre's process, which has received the appellation of the *Daguerreotype*, is entirely different, and the results more striking and beautiful. The essential parts of this process are as follows: A thin sheet of silver or plated copper is first polished with care, and exposed a few minutes to the action of vapor of iodine, by which an exceedingly

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123. What is photography? How is paper prepared for photographic purposes? How are pictures formed in this mode fixed, or rendered permanent? How must photogenic paper be preserved?

124. Describe the Daguerreotype process.



thin coating of iodide of silver is formed upon the surface. It is then placed in a camera obscura, and the image of any object in front is made to fall upon it for a few moments, by which such a chemical change is produced in the thin coating of iodide of silver, that subsequent exposure to the vapor of mercury, at a moderate temperature, brings out a beautiful picture of the object.

Instead of pure iodine, the bromide or chloride of iodine may be used for preparing the plates; but the last compound is said to be, on the whole, much the best.

The picture, when taken from the mercurial process, is rendered permanent by removing the coating of iodide of silver, which is readily done by merely pouring over it a warm solution of hyposulphite of soda or of common salt.

The Daguerreotype process is very simple, but to insure success, close attention must be paid to various minute particulars, which cannot here be discussed.

125. *Double refraction* of light takes place when a ray is passed through certain transparent crystals, and some organized substances, so that objects seen through them in particular directions appear double; and the rays emerging from them are found to have undergone a further change, by which they have acquired peculiar properties on different sides, and are said to be *polarized*. Light is also polarized by other means, as by reflection at particular angles from most non-metallic substances, and by refraction. For a very full discussion of the subject, see *Natural Philosophy*, p. 209.

Rays of heat may be polarized in the same manner and by the same means as those of light.

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125. What is meant by the double refraction of light? What is meant by the polarization of light? May rays of heat be polarized?

## ELECTRICITY.

## NATURE AND SOURCES OF ELECTRICITY.

126. NATURE OF ELECTRICITY.—As in the cases of heat and light, we know nothing of the real nature of electricity, all our knowledge on the subject being limited to its effects.

Like heat and light, it is imponderable; no accumulation of it in any substance adding to the weight of that substance, even when tried by the most delicate balances; but many of its effects are so like those of a mechanical agent, that it is usually considered a separate material substance.

127. When certain substances, such as amber, glass, sealing-wax, and sulphur, are rubbed with dry silk or cloth, they are found to have acquired a property, not observable in their ordinary state, of causing contiguous light bodies to move towards them; or, if the substances so rubbed be light and freely suspended, they will move towards contiguous bodies. After a while this curious phenomenon ceases; but it may be renewed an indefinite number of times by friction. This property was first noticed in amber; and therefore the principle thus developed was called *electricity* (from the Greek, *electron*, amber).

When a substance, by friction or other means, acquires the property just stated, it is said to be *electrified*, or to be *electrically excited*; and its motion towards other bodies, or of other bodies towards it, is ascribed to a force called *electric attraction*. But its influence, on examination, will

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126. Do we know anything of the real nature of electricity? To what is our knowledge limited? Why is it considered imponderable?

127. What are the phenomena observed when certain substances, as amber, glass, &c., are rubbed with dry silk? From what is the term electricity derived? When is a body said to be excited?

be found to be not merely attractive; on the contrary, light substances, after touching the electrified body, will be disposed to *recede* from it just as actively as they approached it before contact. This is termed *electric repulsion*.

128. In the absence of positive knowledge in regard to the nature of this agent, two *theories* have been proposed to account for and connect the established facts.

*Dufay's theory* (from the name of its proposer) supposes that every substance, in its *natural state*, contains in itself two highly subtile and elastic fluids, in such a state of combination that the presence of each is entirely disguised; but that the various phenomena of electrical excitement are produced by one or the other of them, accumulated in a body in excess. The particles of each fluid are supposed to bear a strong attraction for those of the opposite kind, and for other matter, but are highly repulsive of each other.

These fluids are supposed to be separated by the various modes of producing electrical excitement, to be hereafter described; and one of them being collected in excess in a body, as just stated, produces the phenomena witnessed.

In most cases, when glass or any other vitreous substance is rubbed, the electricity which is collected is the reverse of that obtained when sealing-wax is subjected to friction; and hence the former is called *vitreous*, and the latter *resinous* electricity.

129. *Franklin's theory* of electricity supposes that all bodies, in their natural state, contain in their substance a certain quantity, called their *natural share*, of a single, subtile, elastic fluid, which produces no sensible effects; but that the phenomena of electrical excitement are produced when the body is made to contain either less or more than

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128. Explain Dufay's theory of electricity. What terms are used to designate the two fluids?

129. Explain Franklin's theory. What terms are used, on this

its natural share. It supposes that the particles of this fluid repel each other strongly, but are attracted by all other matter. When a body contains more than its natural share, it is said to be *positively* electrified; and *negatively* electrified, when it contains less.

Glass and other vitreous substances, when rubbed, are supposed to take more than their natural share of the fluid, or become *positive*; while resinous substances, in the same circumstances, lose a portion of their natural electricity, or become *negative*. These states are often indicated by the algebraic signs + and —.

The terms *vitreous* and *positive*, of the two theories, are therefore synonymous, as are also the terms *resinous* and *negative*.

Either of these theories is found to answer well in explaining most of the phenomena of electricity, but that of Dufay is generally preferred, though the terms positive and negative, of Franklin's theory, are almost universally used.

From the above it will readily be seen, that when two bodies are either positively or negatively electrified, they repel each other, but attract each other when one is positive and the other negative.

130. *Conduction of Electricity*.—Some substances allow the electric fluids to pass over them freely, and are therefore called *conductors*; while others, that refuse it a passage, or allow it to pass but slowly, are called *non-conductors*. If electricity be imparted to one end of a conductor, such as a copper wire, the other extremity of which touches the ground, or is held by a person standing on the ground, the

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theory, to indicate the two electrical states of bodies? How are these states sometimes indicated? Which of the above theories is generally adopted at the present time? When will two bodies attract, and when repel each other?

130. What are conductors? What are non-conductors? What is the effect of imparting electricity to a conductor, any part of

electricity will pass along its whole length and escape in an instant, though the wire were several miles long; whereas excited glass and resin, which are non-conductors, may be freely handled without losing any electricity except at the parts actually touched.

To the class of conductors belong the metals, charcoal, plumbago, water, and aqueous solutions, and substances generally which are moist, or contain water in its liquid state, such as animals and plants, and the surface of the earth. These, however, differ in their conducting power. Of the metals, silver and copper are found to be the best conductors; and after these follow gold, zinc, platinum, iron, tin, lead, antimony, and bismuth. Aqueous solutions of acids and salts conduct much better than pure water.

To the list of non-conductors belong glass, resins, sulphur, diamond, dried wood, precious stones, earth, and most rocks when quite dry, silk, hair, and wool. Air and gases in general are non-conductors if dry, but act as conductors when saturated with moisture.

It is not, however, to be understood that any very definite line can be drawn between the two classes of conductors and non-conductors; but there seems to be a very regular gradation from the most perfect conductor to the most imperfect, or most perfect non-conductor. This division of substances is, however, found very convenient, though in some instances individuals might differ with regard to the class to which a particular substance is to be assigned.

131. When a conductor is supported upon a non-conducting substance, it is said to be *insulated*, and electricity may be retained upon it for a time; but even then it will be gradually diffused and disappear. This is occasioned in part

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which touches the ground? What are some of the conductors mentioned? What non-conductors are mentioned?

131. When is a conductor said to be insulated? Why cannot

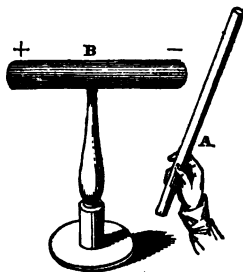
by the conducting power of the air, which is considerable, except when it is very dry. In damp weather, many electrical experiments cannot well be performed, because of the rapid diffusion of the fluid through the air, and the deposition of moisture upon the surfaces of insulators.

When two substances are rubbed together, both electricities are always developed, one of them going to one of the substances, and the other to the other substance; and both electricities may be retained, if the two substances rubbed together are insulated.

The diffusion of electricity from an excited conductor depends much upon its form: if the conductor be perfectly spherical, it is retained longest, but tends to escape rapidly, if there are any projecting points. So, also, the fluid is received more readily upon pointed conductors than upon plane or curved surfaces.

### 132. *Induction of Electricity.*—

An electrified body always exerts a peculiar influence on the natural electricity of other bodies in its vicinity, called *induction*, the nature of which will be seen from the following explanation: Let A be a positively excited glass tube, held near one end of an insulated conductor, B, supposed to be in its natural state; the natural electricity in B will instantly be disturbed, and, on examination, it will be found that the end



electrical experiments be well performed in damp weather? When two substances are rubbed together, are the two electricities always developed? How may both be collected? Upon what does the diffusion of electricity from an excited conductor depend? What is the effect, if there are points projecting from it?

132. What is the effect upon the natural electricity of an insulated conductor, when an excited body is brought near it? In what state will the part of the conductor nearest the excited body

next the excited glass is negatively electrified, and the other end positively, as shown by the algebraic signs. If, instead of the glass tube, some other substance, negatively electrified, had been used, the electricities of the two ends of the conductor B would have been reversed. In every case, the part of the conductor next to the excited body will be in the opposite state of excitement, while the other end will be in the same state as the excited body.

In the experiment, nothing but air is supposed to be between the excited body A, and the conductor B, but the inductive influence is exerted through all non-conductors. Thus, if a clean and dry pane of glass be held between A and B, the result will be the same.

133. *Electrometers.*—Electrometers are instruments for indicating the presence of electricity, or its intensity. A pith-ball, suspended by a dry silk thread from any convenient support, answers the purpose quite well; but the following, called the gold-leaf electrometer, is a more sensitive instrument. It consists of two slips of gold-leaf, suspended in a cylindrical glass vessel, from a metallic plate at the top. If the bottom is also made of metal, its sensitiveness will be increased. When an excited body is brought near the metallic plate, the leaves at once diverge, in consequence of the inductive influence (132) of the excited body, as already explained.



134. *The Leyden Jar.*—The Leyden jar, so called from the fact that it was invented in the city of Leyden, in Holland, consists of a glass jar, coated both inside and outside with tin-foil, except a part around the top, as

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be? Does any electricity pass from the excited body to the conductor? Will the influence be exerted through other bodies?

133. What is the electrometer used for? What answers well for this purpose? Describe the gold-leaf electrometer.

134. How is the Leyden jar constructed? When positive elec

shown in the figure. Through a varnished wooden cover, A, a wire, having a knob at top, is passed, and a chain, B, extends to the inside coating. Now, when either positive or negative electricity is communicated to the knob at the top, it is immediately diffused over the whole inside coating; and by its inductive influence, the outside coating (which must not be insulated) takes on the opposite kind. When in this state,—the two coatings being oppositely electrified,—the jar is said to be *charged*; and a *discharge* takes place when a communication is established between the knob and the outside coating, the equilibrium being restored with a bright flash of light and a sharp report. As the human system is a good conductor, this discharge may take place through it, by grasping the outside coating with one hand, and touching the knob at the top with the other; or several persons may form a line by grasping hands, the one at one extreme touching the outside coating, while the one at the other extreme touches the knob. All will feel the shock, as it is called, at the same instant.



135. **SOURCES OF ELECTRICITY.**—As we have seen above, electricity is believed to be contained in all bodies, which are therefore properly its sources; but the earth, as being by far the largest mass to which we have access, is its chief source. We propose, however, under this head, to speak of the different modes of exciting or collecting it, which are *friction, change of temperature, and chemical action.*

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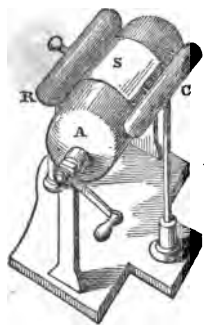
tricity is communicated to the inside, why does the outside become negative? How is it discharged? How may a person receive the discharge through his system?

135. What is the chief source of electricity? What different modes of exciting electricity are mentioned? If both fluids are developed when two substances are rubbed together, why do they not always manifest themselves?



**X** *Friction, as a Source of Electricity.*—It is believed that electricity is always developed when one substance is rubbed against another, one of the fluids passing to one of the substances, and the other to the other substance, as before stated; but, in most cases, neither of the fluids is retained, because the rubbing substances are not insulated. If both be insulated, both the positive and negative fluids may be retained (131).

136. *The electrical machine* is an instrument for developing electricity by friction, more abundantly than it can be done by the simple means heretofore pointed out, though most of the great principles of the science, as we have seen,



may be demonstrated without it. The figure in the margin represents the cylinder machine in its usual form; and in the author's *Natural Philosophy*, p. 278, will be found a description of an elegant plate machine. A is a cylinder of glass, firmly supported, and capable of being turned on its axis by a handle; and R is a conductor, supported on a pillar, having the rubber attached to it, with a flap of silk, S, extending nearly over the cylinder. C is made of sheet-brass, and is

called the prime conductor, because it receives the electricity from the cylinder as it is turned, by means of several pointed wires (129), extending inwards towards the cylinder. It is supported upon a pillar of glass.

Now, when the cylinder is turned, electricity is abundantly developed by the friction of the rubber against its surface, and is received by the prime conductor, in which it accumulates. The use of the flap of silk, S, is to prevent the fluid from escaping in the air, as the cylinder is turned.

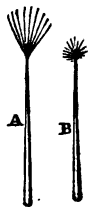
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136. What is the design of the electrical machine? Describe the machine. Where is the electricity developed? Where is it

From the principles heretofore discussed, the learner will readily perceive that it is the positive electricity that will be accumulated in the prime conductor; but the negative (131) will also at the same time accumulate in the rubber, if it be insulated. But no considerable quantity of electricity can usually be collected, unless the rubber communicates with the earth, or, which is the same thing, with the floor of the room.

When used, the machine should be dry and warm, and perfectly clean and free from dust. Its action is also greatly increased by spreading the surface of the rubber, where it presses against the cylinder, with a soft amalgam of zinc, tin, and mercury.

When the machine operates properly, if the knuckle be presented near the prime conductor, a vivid spark passes between them, and a slight stinging sensation is felt; the same thing also takes place on presenting the knuckle to the rubber, provided it be insulated. If a needle is fixed in the prime conductor, with its point projecting from it very little, no electricity can be collected (131); and if the room be dark, its escape from the points will be shown by a brush of faint blue light, as represented in the figure A. If the needle is held in the hand, with its point near the conductor, the accumulation of electricity in the conductor will also be prevented, a faint light, in the form of a star, being seen upon its point, as shown by B, in the figure.

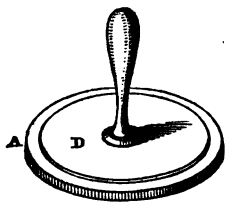


137. *The Electrophorus* (from *electron* and *phero*, I bear) is an instrument for readily obtaining small

collected? Which electricity is it that accumulates in the prime conductor? Can any considerable quantity be collected when the rubber is insulated? Why is amalgam spread upon the rubber? Why cannot electricity be collected when a needle is fixed in the prime conductor? If the room be dark, what will be seen at the point of the needle? What will be the effect, if the needle is held in the hand, with the point near the prime conductor?

137. What is the design of the electrophorus? How is it con-

quantities of electricity. It consists of a plate of resin, A, about 12 inches in diameter, contained in a shallow dish of metal, and a metallic disk, D, a little smaller than the plate of resin, provided with a glass handle, for removing it from the resin at pleasure. To operate well, the surface of the resin should be perfectly smooth.



To charge the electrophorus, the disc is removed, and the surface of the resin rubbed briskly with a piece of warm, dry flannel, or a silk handkerchief, by which negative electricity is excited. If, now, the disc of metal be restored by means of its insulating handle, its lower surface will become positive by induction (132), and its upper surface negative. By touching the upper surface of the disc, when in this position, with the finger, the negative electricity will be discharged; and if it be then removed carefully by its handle, it will be found highly charged with positive electricity, so that a considerable spark may be obtained from it. As the cake of resin has lost nothing of its electricity by the operation, the process may be repeated any number of times, with the same result.

*The Hydro-Electric Machine* is an instrument for exciting electricity by means of high-pressure steam. The excitement is attributed to the friction of the steam, carrying with it drops of water, against the pipes from which it issues.

138. *Atmospheric Electricity*.—The general phenomena of thunder and lightning are well known. They are occasioned, as Franklin first demonstrated, about a century ago, by immense accumulations of electricity in the clouds, between which and objects upon the earth, violent discharges

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structed? How is it used? What is the hydro-electric machine?

138. How are thunder and lightning occasioned? What are lightning-rods?

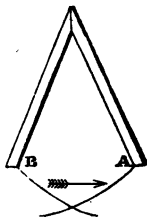
are frequently taking place. The discharge is believed to differ in nothing from the discharge of a spark from the conductor of an electrical machine, except what necessarily results from the quantity and intensity of the fluid accumulated.

*Lightning-rods*, which are so common at the present day, are rods of metal erected upon buildings, extending a distance above them at the top, and at the bottom connecting with the moist earth. Being made of metal which is a good conducting material, any discharge that may happen upon the building will be conveyed by them without danger to the ground.

Electricity excited by friction is frequently called *statical electricity*, to distinguish it from *dynamic electricity*, which will be hereafter described, under the head of Galvanism.

139. *Change of Temperature, as a Source of Electricity; Thermo-Electricity.*—If a crystal of tourmaline, the extremities of which are dissimilar, is slightly heated in the flame of a spirit-lamp, one end will be found, on examination by a delicate electrometer, to be positive, and the other negative; but the excitement is very feeble. Crystals of some other substances may be excited in the same manner.

But the more common method of exciting electricity by change of temperature, is to heat slightly the ends of two or more small rods of different metals at their junction, as represented in the figure. Let A be a small rod of antimony, and B another of bismuth, soldered together at one end; and then let the heat of a spirit-lamp be applied, for a moment, at the point where they are soldered: while the bars are warming, the bismuth will be negative, and the antimony positive. The bismuth is called the positive, and the anti



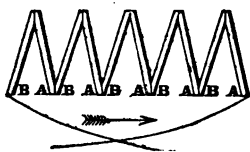

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139. How may a crystal of tourmaline be excited? What is the usual method of exciting electricity by heat? What metals may

mony the negative metal, because, while heating, the positive fluid appears to originate in the former, and flow to the latter; but an electrometer will show the different states of the metals, as above indicated.

Other metals—and even non-metallic substances—may be used, with similar results. German silver and brass answer very well, the former corresponding in its action with the antimony, and the latter with the bismuth.

The effect will be considerably increased, if several pairs of the metals, arranged as above, are associated together, as



shown in the accompanying figure, the alternate rods, A, being of German silver, and the intermediate ones, B, of brass. When the metals are gently heated at the points of junction at one extremity

of the bars, and kept cool at the other, the terminal bars become excited, and a constant current flows over any conducting substance, as a copper wire, connecting the extremities of the series. If the upper ends of the rods be heated, the direction of the current over the wire will be as shown by the arrow. If the lower ends be heated, or the upper ends cooled, its direction will be reversed.

The existence and direction of these currents are best shown by a delicate *galvanometer*, an instrument to be hereafter described.

By reversing the experiment, and passing a current of electricity through the series of bars, they will be heated or cooled, according to the direction in which the current is made to pass.

An instrument formed in the manner above described, but

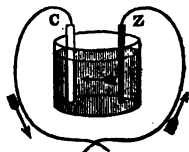
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be used? How may the effect be considerably increased? What will be the effect of reversing the experiment, and passing a current of electricity through the apparatus? What is the apparatus called?

with the bars of metal arranged in a more compact form, constitutes the *thermo-multiplier*, which is much more delicate in indicating slight changes of temperature than the most sensitive thermometer.

140. *Chemical Action, as a Source of Electricity.*—Chemical action, as the solution of a metal in an acid, and the combustion of charcoal in an ordinary fire, it is believed, is always attended by the developement of electricity. In the combustion of charcoal, the gas arising from the coal is positive, while the coal itself, if insulated, is negative; and when a metal is dissolved in acid, a current of positive electricity always passes from the metal to the liquid, and any conducting substance, as a plate of copper, contained in it.

Let Z be a zinc plate immersed in water, acidulated with a little sulphuric acid, contained in a glass vessel, and C a plate of copper, also immersed in the same liquid; the zinc will be gradually corroded, and a current of positive electricity pass from it through the liquid to the copper; and if the plates are connected by a wire, the current will pass over it in the direction indicated by the arrows.



But, although we have, in these and other cases of chemical action, such decided and even powerful developements of electricity, it is admitted, that in very many cases where chemical action really takes place, no indications of electricity have as yet been observed. The action of one salt upon another, of one metal upon another, or of a simple element, as oxygen or sulphur, upon a metal, may be men-

140. Is chemical action always attended by the developement of electricity? When a zinc plate is acted upon by an acid, what is its electrical state? If a plate of copper is immersed in the same liquid, at a little distance from the zinc, what will be its state? If the plates are then connected by a wire above the liquid,

tioned, as instances in which no electrical excitement is actually known to take place.

The electricity of chemical action, sometimes called *dynamical electricity* (138), properly constitutes the subdivision of the general subject of electricity called GALVANISM; and under this title it will be discussed more at length, as it is this branch of the general subject which more especially concerns the student of chemistry.

### GALVANISM.

141. GALVANIC ARRANGEMENTS, OR CIRCLES.—The science of Galvanism owes its name and origin to the experiments on animal irritability made by Galvani, professor of anatomy at Bologna, Italy, in the year 1790. In the course of some of his investigations, he discovered the fact that muscular contractions are excited in the leg of a frog recently killed, when two metals, such as zinc and silver, one of which touches the crural nerve, and the other the muscles to which it is distributed, are brought into contact with one another.

The experiment with the legs of a recently killed frog is easily repeated, in the following manner:—After killing the frog, immediately separate the hind-legs, with a small portion of the spine, and remove the skin; then bind around the part of the spine removed with the legs, a piece of tin-foil, F, and, holding it up with the left hand, apply a piece of silver coin, or a rod of silver, S, bent, if necessary, so that it shall touch the tin-foil and the flesh of one of the legs at the same time. At each contact of the metals, the muscles

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what will be the effect? What is the electricity of chemical action usually called?

141. What was the discovery of Galvani in connection with this subject? Describe the experiment with a frog.

of the leg will be violently contracted, and jerking of the legs produced. The experiment succeeds best when the whole is kept wet with clean water. The irritability of the muscles will gradually subside, but sometimes it will continue more than an hour after the death of the animal.

The large legs of some insects, especially those of the grasshopper, may be used for the same purpose.

142. *Simple Galvanic Circles.*—A simple galvanic circle is formed of three substances, two of which are usually metals, and the third a liquid. The arrangement described in paragraph 140, constitutes such a circle. The zinc is acted upon by the acid, and the electrical disturbance takes place over all that part of its surface covered with the liquid. This part of the plate becomes positive, while the part above the liquid becomes negative. If, now, a plate of copper, or other metal not capable of being acted upon by the liquid, be introduced, it will become positive by receiving electricity from the liquid; and, by connecting the two plates by wires, a constant current is established over these wires, as shown by the arrows. It matters not, so far as galvanic action is concerned, at what part the plates touch each other. A current is formed, whether contact between the plates is made below, where covered with liquid, above, where uncovered, or along the whole length of the plates, provided both plates are immersed in the same vessel of diluted acid. But in every case a circuit must be formed, around which the electricity may traverse, either in a single current, or in many partial currents, into




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142. How is a simple galvanic circle formed? In what direction will the current pass? What will be the effect, if the plates are in contact beneath the liquid? When is the circle said to be



which it may divide itself, as will be the case when the metals are in contact along their whole surfaces. This last result it is desirable to avoid; and therefore the metals are always to be kept separate below the liquid, and above it also, except at the part where the current is desired to pass. Usually, a wire is connected with each plate, which may be brought in contact or separated at pleasure. When they are in contact, the circle is said to be *closed*; when they are separated, it is said to be *broken*.


A simple galvanic circle may be formed of one metal and two liquids, provided the liquids are such that a stronger chemical action is induced on one side than on the other. Nay, even a plate of metal, with two portions of the same liquid, may be made to constitute the simple circuit, provided only the conditions are such that one side of the metal shall be acted upon by the liquid more readily than the other. This will be effected, if one portion of the liquid is warmer or stronger than the other, or if one surface of the metal is rough and the other polished.

We have above represented the positive current as passing from the zinc, through the liquid, to the copper, and in the opposite direction over the wires connecting the plates above the liquid; this will always take place when a diluted acid is used, which attacks the zinc more violently than it does the copper; but if a solution of ammonia be substituted for the acid, the copper will be most acted upon, and the current will move in the opposite direction.

It is not necessary that copper and zinc alone should always be used in these experiments; other metals may be adopted, with equal, and, in some cases, with even more

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closed? When open? May the galvanic circle be formed by other means than the particular ones just described? In what direction will the current pass, if a solution is used that acts more upon the copper than upon the zinc? May other metals besides copper and zinc be used? What are the conditions required?

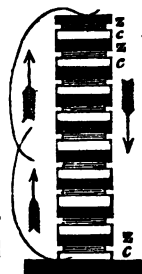


decisive results. Nor is it required that the liquid should always contain an acid; other substances, as solutions of the salts, are quite as efficacious in exciting this subtile fluid. The conditions required are, that the metals and liquid used should be such that chemical action will take place more readily between one of them and the liquid than between the other and the liquid; and that metal is always found positive (below the surface of the liquid) which is most acted upon by it. Other things being equal, the galvanic action will be more intense, the greater the difference between the two metals used, as regards their tendency to be acted on by the particular menstruum in which they are immersed.

Besides the above arrangement, there are several modifications of the simple galvanic circle, each possessing its own peculiar advantages, which will shortly be fully described.

**143. Compound Galvanic Circles.—Galvanic Batteries.**—The compound galvanic circle, or galvanic battery, consists of a number of simple circles, so arranged in a series, that the copper of each simple circle is connected with the zinc of the one adjacent. One extreme of the series, it will be evident, will be copper, and the other zinc; they are often called the *poles* of the battery, the former being positive and the latter negative.

The *voltaic pile* (from the name of its inventor) deserves here to be noticed, as the earliest and simplest instrument of this kind, though by no means the most efficient. It is formed of pieces of copper, *c*, zinc, *z*, and cloth, the latter being moistened with solution of salt or acidulated water. Commencing with either of the metals, upon this is placed a piece of cloth, and then a piece of the other

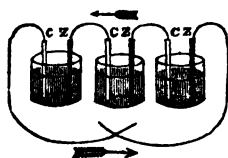


143. Of what does a compound galvanic circle consist? Describe the voltaic pile. How many pairs of plates may be used with advantage?

metal; the three, of course, constituting a simple galvanic circle. Upon this circle other simple circles are then formed in the same manner, care being taken to place the metals throughout the series in the same order.

The series may be extended indefinitely; but, usually, from fifty to one hundred pairs of metallic plates will be found as many as can be employed advantageously. When in action, the extreme zinc plate, which is represented as uppermost in the figure, will be negative, and the extreme copper plate positive; and if they be connected by wires, the current will flow in the direction of the arrows, both through the series, and over the wires. The extremes of the series are called its *poles*, or *electrodes* (from *electron*, and *odos*, a way).

144. An excellent compound circle, or battery, is formed by combining a number of cups like that represented in paragraph 140. Each cup contains a zinc and copper plate,



the zinc of one cup being connected with the copper of the next, through the whole series, leaving the two extreme plates free; and the cups are filled with diluted acid, or a solution of salt. The two free plates, constituting the extremities of the series, will be the poles,

or electrodes; and when they are connected by wires, the current will be established in the direction of the arrows.

By studying closely this arrangement, it will be seen that the actual quantity of electricity flowing over the wires connecting the electrodes, is no more than when a single cup only, with a single pair of plates, is used. The same elec-

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144. Where are the poles or electrodes of the compound circle? How does it appear that the whole quantity of electricity circulating over the polar wires of the compound circle is equal only to that developed by the extreme plates?

trical disturbance, we suppose, takes place in each cup, over the whole surface of the zinc plate which is covered with the liquid, the part of this plate above the liquid becoming negative, and the liquid becoming equally positive; the copper plate then serves as a conductor to take up this positive electricity, and convey it to the negative zinc of the next cup, by which it will be exactly neutralized. However extensive the series may be, this will take place with every alternate zinc and copper plate except the extreme ones; so that the quantity passing over the wires connecting the electrodes, will be only that of the single pair of plates constituting the extremes of the series.

145. But although the *quantity* of electricity developed at the electrodes of the compound circle is no more than we should obtain by using a single pair of plates, yet it will be found to have acquired a very important property, called *intensity*. By this term is meant its power to overcome resistances which may impede the passage of the current. The current from a single pair of plates, however large they may be, will always be exceedingly feeble, and will not flow unless the wires connected with them are in actual contact; but, if the polar wires of the compound circle are once brought in contact, they may be separated at a little distance, and the current will continue to pass between them, with a brilliant flame. The reason is, because the current from the compound circle possesses sufficient *intensity* to overcome the resistance of the thin stratum of air between the wires, which is not the case with the current of the simple circle.

So, if the polar wires of the simple circle are grasped, one in each hand, by the operator, not the least sensation is felt, because there is not sufficient *intensity* to impel the current

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145. Although the quantity of electricity put in motion is not increased by increasing the series, what important effect is produced? Will the current of a single pair of plates always be fee-

through the system, which is comparatively a poor conductor; but if the same is done with the polar wires of the compound circle, especially if the series be extensive, the moment the circuit is formed, a powerful shock is experienced, similar to that received from the Leyden jar. This is owing to the increased intensity of the current from the compound circle, enabling it to overcome the resistance which is interposed. •

146. From the above facts we deduce this important practical principle: that, to produce a current of quantity, a single pair only of large plates is wanted; but to give intensity, a number of simple circles must be combined, in the manner described.

The energy of any battery, whether composed of one or many simple circles, will depend very much upon the nature of the liquid used. A solution of common salt, sulphate of soda, nitrate of potassa, alum, or other salt, will answer the purpose, but acids are much better. Generally, one of the stronger acids is used, diluted with 15 or 20 times its weight of water. For ordinary purposes, a mixture of equal parts of nitric and sulphuric acids, diluted with 20 times their weight of water, will be found to answer well.

147. *Nature of the Chemical Action in the Galvanic Battery.*—The development of electricity by the usual galvanic arrangements, is attributed chiefly, if not entirely, to the decomposition of water in contact with the zinc plates. Water is a compound of oxygen and hydrogen, and is inca-

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ble? What will be the effect when the poles of the compound circle are grasped by the hands? Why will not the same effect be produced by the simple circle?

146. What important practical principle is deduced from the above facts? Upon what will the energy of any battery always depend? What mixture of acids is recommended?

147. To what is the development of electricity in the usual galvanic arrangements chiefly attributed? Of what is water com-

pable of acting upon zinc, unless some acid be also present. But when a piece of this metal, in its usual impure state, is immersed in diluted acid, the water is decomposed, its oxygen combining with the zinc, forming oxide of zinc, while the hydrogen rises in bubbles and escapes in the air, and at the same time the oxide of zinc is taken up by the acid. If, now, a plate of copper is placed in the diluted acid, at a little distance from the zinc, and the two connected by a wire, constituting a simple galvanic circle (142), the bubbles of hydrogen will not rise around the zinc as before, but around the copper; showing that the gas has in some way been transmitted through the liquid between the plates, though not the least appearance of any motion can be observed by the eye. If the connecting wire is removed, the evolution of hydrogen at the copper plate at once ceases with the cessation of the electrical current, but continues to rise slowly around the zinc.) This latter effect, however, is occasioned by the impurity of the zinc. Thus it would seem that the development of the current is occasioned entirely by the decomposition of the water, and the formation of oxide of zinc.

When the battery is in active operation, though the hydrogen is rapidly evolved at the copper plates, yet the whole surfaces of these plates will be all the time covered with a film of this gas, which interferes with its conducting power, and prevents the free passage of the current; at the same time, as a matter of course, diminishing very considerably the energy of the battery. To remedy this difficulty, seve-

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posed? What takes place when a plate of zinc is immersed in dilute acid? What becomes of the hydrogen, when a plate of copper is connected with the zinc and immersed in the liquid? Can the movements of the hydrogen through the liquid be observed? What is the effect of removing the wire which connects the plates? What is observed on the copper plates when the battery is in active operation? What disadvantageous effect is produced by it?

ral new forms of the battery have recently been invented, which act with great energy, and will here be briefly described.

148. *Daniel's Constant Battery.*—This excellent instrument consists of a cylindrical vessel of copper, C, in which is placed another smaller one, L, made of uncoiled leather, or unglazed porcelain, through which water will gradually percolate; and in the latter is contained a rod of zinc, Z, about an inch in diameter. To charge it, the inner porous vessel, which contains the rod of zinc, is filled with diluted sulphuric acid (acid 1 part and water 8 parts), and the space around the inner vessel with a saturated solution of



blue vitriol, acidulated with sulphuric acid. To the side of the copper vessel, and also to the zinc rod, wires are soldered, with binding screws for holding the polar wires; the one connected with the copper being positive, and the other negative, as shown by the algebraic signs.

Usually, the zinc rod is amalgamated with mercury, which is done by rubbing the surface with mercury, while covered with some weak acid. This renders the chemical action over the whole surface more uniform, and the action of the battery more constant; but the same thing may be accomplished with less trouble, by using the zinc in its ordinary state, and substituting, in the porous cell, a saturated solution of sulphate of soda (Glauber's salt), instead of the diluted acid.

The above arrangement, it is plain, constitutes a simple galvanic circle; and its action is particularly energetic and constant, in consequence of the accumulation of hydrogen

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148. Describe Daniel's constant battery. How is the zinc rod amalgamated? What is the benefit of this? How may the same object be accomplished with less inconvenience? How is the hy-

gas upon the copper plate (147) being completely avoided. This will appear from the following explanation.

In this instrument, as in the more common one first described (142), the electricity is developed at the surface of the zinc, by the decomposition of the water; the oxygen combining with the zinc, and the hydrogen passing through the porous vessel into the vitriol solution, and thence to the sides of the copper vessel, which constitutes the copper plate of the series (140). Here the hydrogen does not make its appearance in bubbles upon the surface of the copper, as in the common arrangement, but enters into a new combination with the oxygen of the oxide of copper deposited from the vitriol solution. Blue vitriol is a compound of sulphuric acid and oxide of copper; and while the battery is in operation, it is all the time decomposing, its acid passing into the porous cup, to act upon the zinc, while the oxide of copper is itself also decomposed, its oxygen combining with the hydrogen at the surface of the outer vessel, which receives a new coating of metallic copper.

Any number of these arrangements may be united, by connecting the zinc of one with the copper of the next, as heretofore described (141); and a battery so constructed has this great advantage, that no action takes place when the circuit is not closed. It is also very constant in its action, affording a uniform current for several hours in succession.

When it is to be used some time, a quantity of undissolved blue vitriol should be kept in the upper part of the copper cell, either upon a shelf provided for the purpose, or in a muslin bag, to keep the solution constantly saturated.

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drogen disposed of in this arrangement? How may these arrangements be combined, so as to form a compound circle or battery? Does any action take place in this battery when the circuit is open?

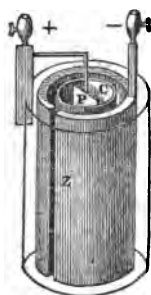


**149. Grove's Battery.**—This battery, invented by Professor Grove, of London, is remarkable, not only for the constancy of its action, but also for its great intensity. It is the battery which is used universally, it is believed, in working the magnetic telegraph.

The construction of this battery is shown in the accompanying figure. A glass or porcelain cup is used, of the size of a common tumbler, and in it is placed a hollow cylinder of zinc, Z, (usually having a slit in one side, to allow a free passage to the liquid), and inside of this, a small cylindrical cup, C, of porous or unglazed porcelain. The glass cup is then filled with diluted sulphuric acid (of the same strength as is used in Daniel's battery), or a solution of Glauber's salt, and the porous cup with strong aquafortis (nitric acid). Lastly, a thin slip of platinum, P, is suspended in the aquafortis, and supported by a piece of wood attached to the side of the glass cup, through which a wire passes, and is bent in the form represented in the figure. A projection upward from the zinc supports a binding screw, shown on the right, and another is soldered to the wire to which the platinum is attached, shown at the left. These, of course, serve as the positive and negative poles of the circle; and to them the polar wires may be attached, when required.

The zinc may be amalgamated, or it may be used in its natural state, provided a solution of Glauber's salt is substituted for the diluted acid (148) in the glass cup.

The action of this battery is essentially the same as that

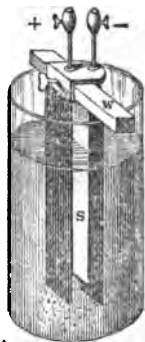



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149. Describe Grove's battery. With what is the porous cup filled? With what the tumbler? For what is this battery especially used? What constitute the positive and negative poles? How is the hydrogen that is liberated expended?

of Daniel's, except that the hydrogen from the decomposition of the water, passing into the porous cell, is expended in decomposing the nitric acid, which, when the instrument is in action, gives off copious nitrous fumes.

150. *Smee's Battery*.—This very efficient instrument is represented in the figure in the margin. Two plates of zinc, well amalgamated, are firmly held together against a piece of wood, W, by means of a brass clamp and screw; and between them is a plate of silver, S, the surface of which has been coated over with metallic platinum, in a state of fine powder, called platinum black. The zinc and silver plates are then suspended in a glass vessel, the piece of wood resting upon the top. A binding screw, constituting the + pole, is connected by a wire (which is insulated from the brass clamp through which it passes) with the silver plate, and another, constituting the — pole, is soldered to the clamp which holds the zinc plates in their places. The liquid used in the glass cup is sulphuric acid, diluted with 10 or 15 times its weight of water.



The peculiar advantage possessed by this form of the battery depends upon the rapid evolution of hydrogen from the platinized silver plate. We have seen above (142) that the accumulation of this gas upon the smooth surface of the copper plate, in the old arrangement, considerably retards the passage of the electric current, by preventing the liquid in a measure from coming in contact with the plate; but this is avoided, in Smee's arrangement, by the roughened surface of the silver plate, produced by the platinum deposit.

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150. Describe Smee's battery. Upon what does the peculiar advantage of this battery depend? Why is it that the hydrogen escapes so freely from the silver plates?

**151. EFFECTS OF GALVANIC ELECTRICITY.**—The effects produced upon bodies by the passage of the galvanic current through them, or sometimes even in their vicinity, are exceedingly various and important. They may be conveniently divided into the four classes of *electrical*, *heating* or *calorific*, *chemical*, and *magnetic* effects.

**152. Electrical Effects.**—By this phrase we mean those effects which are analogous to those produced by ordinary or statical (138) electricity. Many of them are best exhibited by the broken circuit, and depend more upon the intensity of the fluid than upon its quantity.

When the circuit of a powerful battery is broken, that is, when the poles or electrodes are disconnected, both of them give signs of electrical excitement, if examined by the ordinary tests; one of them being positive, and the other negative, as before explained.

A Leyden vial may also be charged by establishing a communication between one of its surfaces and one of the electrodes, while the other surface is connected with the other electrode; but the charge will always be feeble.

Either of the electrodes will give a spark to a conductor presented to it, but it is shown best by bringing the two polar wires in close proximity; and on establishing the communication between the electrodes by the hands, previously moistened, a powerful shock is felt, precisely like that produced by the discharge of the Leyden jar.


**153. Heating or Calorific Effects.**—When the communication between the electrodes is established by means of

151. Into what four classes may the effects of galvanic electricity be divided?

152. What is meant by the electrical effects? How are many of them best exhibited? When will the poles of a powerful battery exhibit signs of electrical excitement? How may the Leyden vial be charged by it? How may a spark be best shown? What will be the effect of grasping the poles with the hands?

153. What is the effect upon a fine metallic wire, when made

fine metallic wires, they very soon become intensely heated, and may even be melted or burnt. Thus, gold or silver leaf, interposed in the circuit, take fire and burn with vivid scintillations.

When pieces of well-burnt charcoal are attached to the polar wires, on bringing them near each other, a most brilliant  arc of flame appears between them, which will continue for some time; and the points are rapidly consumed, as if heated by any other means. But the heating effect does not depend upon the combustion of the coal, since it is equally as great when the charcoal points are excluded from the air.

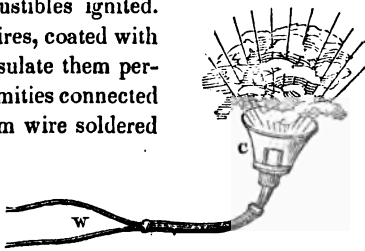
The heating effect of a galvanic current may be produced at great distances from the battery, and gunpowder or gun-cotton and other combustibles ignited.

Let W be two copper wires, coated with tarred twine, so as to insulate them perfectly, having their extremities connected by a very small platinum wire soldered to them, as shown

through the glass cup

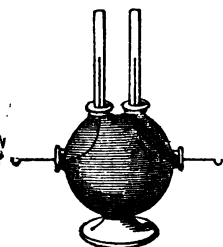
C. Let the cup be now

filled with gunpowder or gun-cotton, and the other ends of the wires brought in contact with the poles of the battery; immediately on the passage of the current, the platinum wire will be heated, and the powder exploded. The wires, if well coated, may be extended under water, and a submarine magazine exploded. This method has been used for exploding the powder in the blasting of rocks.



to connect the poles? How may gold and silver leaf be ignited? How may charcoal points be ignited? May the heating effects be produced at a great distance from the battery? Describe the method of exploding gunpowder or gun-cotton. How may a submarine magazine be exploded?

154. *Chemical Effects.*—The chemical effects of the galvanic current are seen chiefly in the decomposition of compound substances, one of the elements making its appearance at the positive, and the other at the negative electrode. Thus, when two gold or platinum wires are connected with the opposite ends of a battery, and their free extremities are plunged into the same cup of water, but without touching each other, hydrogen gas is disengaged at the negative, and oxygen at the positive wire. By collecting the gases in se-



parate tubes as they escape, as in the apparatus figured in the margin (the wires of which are seen at the sides, and extend into the tubes above), they are found to be quite pure, and in the exact ratio of two measures of hydrogen to one of oxygen.

If other compound bodies, such as some acids and salts, are exposed to the action of galvanism, they are also decomposed, one of their elements appearing at one side of the battery, and the other at its opposite extremity. An exact uniformity in the circumstances attending the decomposition is also remarked. Thus, in decomposing water or other compounds, the same kind of body is always disengaged at the same side of the battery. The metals, inflammable substances in general, the alkalies, earths, and the oxides of the common metals, are found at the negative wire; while oxygen, chlorine, and the acids, go over to the positive surface.

Those substances which appear at the positive side have been called *electro-negative* bodies, while those that are

154. In what are the chemical effects of galvanic electricity chiefly seen? Where do the elements of the compound make their appearance? How may water be decomposed by the battery? At which pole are inflammable substances, the alkalies, and alkaline earths, &c., found? At which pole oxygen, chlorine, and the acids? What are electro-positive, and what electro-negative bodies?

separated at the negative wire are called *electro-positive* bodies.

The decomposition of a salt, which must be in solution, may be shown in the following manner:—Let two wine-glasses be filled with a solution of sulphate of soda, which is a compound of sulphuric acid and soda, and let some fibres of moistened cotton be extended between them, as shown in the figure. If the current is then transmitted through the cups, the salt will soon be decomposed, and the cup in connection with the positive electrode will be found to contain weak sulphuric acid, and that in connection with the negative electrode a solution of soda. If, now, a little red cabbage-water be poured into each, the acid liquid will become red, and the soda solution green.



155. Contrary to what we might expect, it has been determined that all compounds (are not) capable of decomposition by this means; and those that are thus decomposable are now very generally called *electrolytes* (from *electron*, and *luo*, to unloose). (The decomposition of a compound is also called its *electrolysis*.) The positive electrode is called the *anode*, and the negative electrode the *cathode* (from *ana*, upward, *kata*, downward, and *odos*, a way).

The elements of a compound capable of separation by this mode, are termed *ions* (from the Greek participle *ion*, going); the *anion* being the element which appears at the anode, and the *cation* the element which goes to the cathode. It will

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How may the decomposition of a salt, as sulphate of soda, be shown? What colors will be produced in the two cups by red cabbage-water? When the salt is decomposed, in which cup will the acid accumulate? In which the soda?

155. Are all compounds capable of decomposition by the electric current? What are electrolytes? Will a substance always make

at once be seen that the anions are electro-negatives (148) and the cations electro-positives.

It is not to be inferred from the remarks in paragraph 154 that every substance will always make its appearance at the same electrode, whatever may be the other substance from which it is separated by the electrolytic action. Oxygen does indeed always appear at the positive electrode, and potassium at the negative; but in the electrolyses of the compounds of other substances, that element will appear at the positive electrode which is *most* electro-negative, and that at the negative which is *most* positive.

156. *Electro-Metallurgy* is the name applied to the deposition of the metals from their compounds by the chemical agency of the galvanic current. We have seen above (147), in describing Daniel's battery, that during its action there is a constant deposition of metallic copper upon the negative plate. Now, if, for the copper plate in this arrangement, a medal, or coin, or other conducting body be substituted, the deposition of the copper upon it will take place in the same manner, and all its minute peculiarities will be copied. An apparatus of this kind, called the *electrotype*, is figured in the margin.



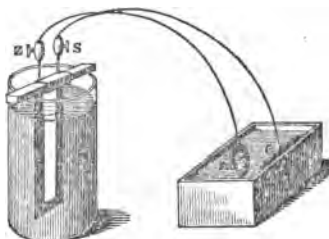
A glass vessel is partly filled with a saturated solution of blue vitriol, containing a little sulphuric acid, and in this is placed a porous vessel, with its rod (147) of zinc, Z, having a binding screw at top. The medal or coin to be copied is then suspended in the vitriol solution by means of a wire inserted

its appearance at the same pole, when separated from a compound by electrolysis?

156. What is meant by electro-metallurgy? Describe the mode of copying a medal by electrolytic action. How may it be done by using a Smee's battery?

in the binding screw. The surface of the medal on which the copper is to be deposited should be perfectly clean, and the other surface should be protected by a coating of wax or varnish. In the figure, two medals, M, M, are supposed to be connected at the same time with the zinc.

A better method than the above is to use a regular Smee's battery, and to have the blue vitriol solution in a separate vessel, as in the annexed figure. Then let the article to be copied, A, be connected with the zinc of the battery, and a plate of copper, C, with the silver, both being suspended, at a little distance from each other, in the vitriol



solution. By the action of the battery, the piece of copper will be gradually dissolved, and a corresponding deposit of metallic copper made upon the medal.

157. Other metals besides copper may be deposited in this manner, but a battery of several cells is in most cases required. The most important application that has been made of this discovery is in depositing silver and gold in thin laminæ upon other metals, called plating or gilding. For this purpose a Daniel's or Smee's battery of about four cells answers well, and a fifth, which is called the depositing cell. This is filled with a solution of cyanide of potassium, and used in the same manner as just described (156) for obtaining a deposit of copper, except that silver or gold must be used instead of the copper, C, according as one or the other of these metals is to be precipitated.

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157. May gold and silver and other metals be deposited in the same manner?



158. *Magnetic Effects.*—The magnetic effects of the galvanic current are exceedingly interesting and important, and constitute a distinct branch of science, called Electro-Magnetism.

### ELECTRO-MAGNETISM.

*Natural Magnet, or Loadstone.*—Among the ores of iron, pieces are often found which possess the property of attracting and retaining pieces of iron or steel with more or less force, and are called *magnets* or *loadstone*. Each magnet always has two points in which the attractive force appears to be concentrated, which are called the *poles*. They are always readily found by rolling the magnet in iron filings, which will be collected more at these points than in other places. Generally they are nearly opposite to each other.



(See figure.) If a magnet is broken into several pieces, each always retains the same magnetic properties as the whole mass, but in less degree. Sometimes a magnet has more than two poles.

159. If a magnet be suspended horizontally by a thread, or placed upon a piece of cork floating in a vessel of water, one of the poles will turn towards the north, and is hence called the *north pole*, and the other towards the south, and is called the *south pole*.

If two magnets thus suspended are brought near each other, it will be found that like poles repel each other, but

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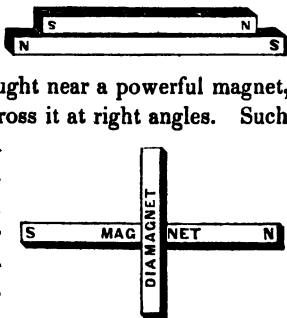
158. What is the natural magnet or loadstone? How may its poles be found?

159. What position will a small magnet take, when made to float upon a piece of cork in water? How are the poles of a magnet designated? When two magnets are suspended near each other, how do like poles affect each other? How unlike poles?

unlike poles attract. These attractions and repulsions extend to some distance, and are not affected by the interposition of other bodies, not capable of becoming magnetic.

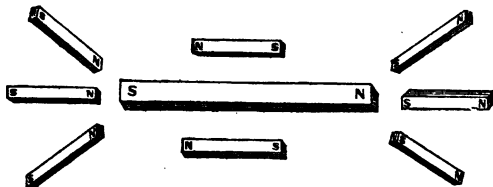
Two magnets of the bar form, placed near each other, and free to move in any direction, would therefore tend to arrange themselves side by side, with their poles reversed, as indicated in the figure in the margin. But recent discoveries have shown that there is a class of substances which, when brought near a powerful magnet, tend to arrange themselves across it at right angles. Such bodies are called *diamagnets*.

The position which a magnet and diamagnet of the bar form tend to take, when brought near each other, is shown in the accompanying figure. The experiment can be shown only by a powerful electro-magnet.



160. *Magnetic Induction*.—When either pole of a magnet is brought in contact with a piece of soft iron, or only very near it, the iron itself becomes magnetic, and remains so until the magnet is removed.

The figure in the margin represents



several pieces of iron, placed in different positions near

160. What is the effect upon a piece of iron, when brought near one of the poles of a magnet? When a piece of iron is attracted by a magnet, is it always rendered magnetic? Does its magnetism remain after it is removed from the magnet?

the poles of a magnet; on examination, they will all be found to have the magnetic property, their poles being developed as indicated by the letters N and S. This influence of a magnet upon pieces of iron, which extends to a distance around its poles, is called its *inductive influence*.



Whenever a piece of iron is lifted by a magnet, this effect is of course produced; and to the first piece a second may be attached, and to the second a third, and so on. When the connection with the first magnet is broken, the pieces of iron instantly lose their magnetism, and fall asunder.

161. Pieces of hardened steel will also be affected in a similar manner, but much less readily, and, unlike iron, they retain the magnetism that has been induced. They therefore become permanently magnetic, and for nearly every purpose are superior to the natural magnet. The same magnet may be used successively to magnetize any number of steel bars, without losing any of its virtue, if the bars be not too large; from which it follows that the magnet communicates nothing to them, but only by its influence develops some hidden principle already there. Artificial magnets are frequently made in the form of the horse-shoe, and are called horse-shoe magnets. To the poles a short piece of soft iron is usually accurately fitted, called the *armature* or *keeper*.

A slender bar of magnetized steel, suspended upon a pivot, so as to revolve freely, constitutes the *magnetic needle*. Sometimes it is attached to a circular card, and suspended upon a pivot, as in the mariner's compass.

162. If a steel bar be suspended by its centre of gravity,

161. Will pieces of steel be affected in a similar manner? Do they retain the magnetism thus acquired? What is the magnetic needle?

162. If a slender bar of steel is suspended by its centre of gra-

and afterwards carefully magnetized, it will be found not only to place itself in the magnetic meridian, but to assume a position inclined to the horizon. In northern latitudes, the north pole will be depressed and the south pole elevated, while in southern latitudes the south pole will be depressed. The angle of inclination is generally nearly the same in the same place, and is called the *dip of the needle*; and a needle nicely balanced and adjusted for showing the dip is called a *dipping needle*.

163. The magnetic needle does not always point to the true north and south, but deviates more or less from this position at different times and places. This is called its *variation*. At Philadelphia, in 1840, the variation was  $3^{\circ} 52'$  W., and at Middletown, Conn., about  $6^{\circ} 40'$ . The dip is also subject to constant change; at the present time it is about  $70^{\circ} 30'$  at Philadelphia, at New York  $73^{\circ} 0'$ , and at Middletown, Conn,  $73^{\circ} 30'$ .

164. *Terrestrial Magnetism*.—The earth may be considered as a great natural magnet, which, by its action on the needle, in the same manner as any other magnet, causes it to place itself in the position of north and south. Indeed, it is by the inductive influence of the earth that magnetism is developed in bodies upon its surface. This is shown in bars of iron or steel that have stood long in a vertical position, which are always found to be magnetic. Tongs and pokers, from their being usually kept in an upright position, are almost always found to be magnetic.

As it has been agreed to call that pole of the needle which vity, and afterwards magnetized, what position will it take? What is the dipping needle?

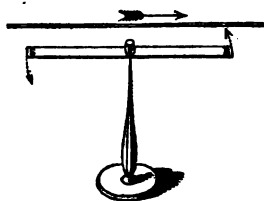
163. What is meant by the variation of the needle? Is the variation constant in any place?

164. What may the earth be considered? How are bars of iron affected by standing long in a vertical position? What is said of tongs and pokers? Which is the north pole of the needle? What kind of polarity must the north pole of the earth have?

points northward, the north pole, it is evident that the pole of the earth situated *north* must be a *south pole*; that is, it must possess *southern polarity*. So, also, the *south pole* of the earth must possess *northern polarity*.

165. *Relation between the Electric Current and Magnetism.*—It has been long known that a discharge of lightning will often affect seriously the magnetic needle, sometimes reversing its poles; but it was not until 1819 that Ørsted made his famous discovery, which has served as the basis of the beautiful science of Electro-Magnetism.

He first observed that when the wire, connecting the electrodes of an active galvanic battery, is brought near a magnetic needle, it is made to deviate from its ordinary position, and assume a new one, depending upon the direction of the current and the position of the wire in regard to the needle. Thus, the needle being in its natural position,—1st, if the connecting wire be above the needle and parallel to it, the pole next the negative electrode will move westward; 2d, if the wire be beneath the needle, it will move eastward; 3d, if the wire is on the west side, this pole will be depressed;



and, 4th, if it be on the east side, it will be elevated. The figure in the margin indicates the motion that will be produced in the first of the above cases.

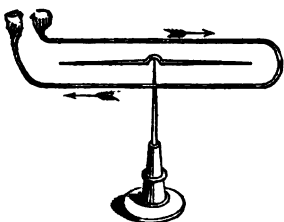
If the wire be placed under the needle, and the current made to pass from north to south, the

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165. What effect is often produced on the magnetic needle by a discharge of lightning? What was the discovery of Ørsted in regard to the effect of a current of electricity upon the magnetic needle? When the current is made to pass over the needle in a line parallel with it, in what direction will the pole next to the negative electrode move? If the current passes under the needle in the opposite direction, what will be the effect? What will be

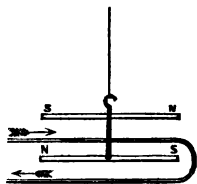
motion of the needle will be the same as indicated in the figure.

Therefore, if the wire be bent around the needle, in the form of a rectangle, so as to convey the current in one direction above the needle, and back again, in the opposite direction beneath it, both parts will conspire to produce the same effect, and the motion of the needle will be much increased. Such an arrangement is represented in the annexed figure.



In all these cases, the tendency of the needle is to settle directly across the wire, or at right angles to the direction of the current, while the influence of the earth is exerted to bring it in its first position, parallel with the wire. The position it will ultimately take will therefore be intermediate between the two.

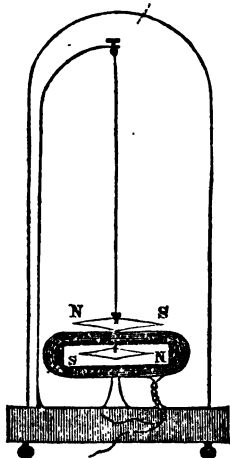
166. To avoid the directive influence of the earth upon the needle, the *astatic* (from the Greek *astatos*, unstable) needle has been contrived. It consists of two needles, of nearly equal strength, fixed to axes, with their poles reversed in reference to each other, and suspended by a thread, as shown in the figure. One of the needles being a little more highly magnetized than the other, or a little larger, they will have a slight tendency to settle in the meridian. If, now, a wire is bent several times around the lower needle, each turn or coil being coated with some



the effect of winding the wire several times around the needle, in the form of a rectangle? In all these cases, what position, in reference to the wire, is it the tendency of the needle to take? Why does it not actually take this position?

166. How is the astatic needle constructed? Why is the con-

insulating substance, when the current is passed around it, its influence on both needles will be to turn them in the same direction; and the arrangement becomes a most delicate instrument for indicating the



passage of the feeblest currents. Such an instrument is called a *galvanometer*. To protect it from currents of air, the whole is usually enclosed in a glass case; and beneath the upper needle, and above the coil of wire, a graduated circle is placed, to indicate exactly the comparative deflections of the needle.

Such an instrument, in connection with a thermo-multiplier (139), becomes a most delicate thermometer, which is capable of indicating a change of temperature of only a very small fraction of a degree.

**167. Tangential Force.**—By a careful inspection of the motions produced in the needle by the current in the several positions of the wire, as described in paragraph 165, it will be evident that the real tendency of each pole is to revolve around the connecting wire in a circle, the plane of which is perpendicular to the wire, the north pole in one direction and the south pole in the other. The force which causes this motion is exerted in lines which are tangents to the circumference of these circles, and is therefore called a *tangential force*.

The motion of the needle *actually produced* will of course

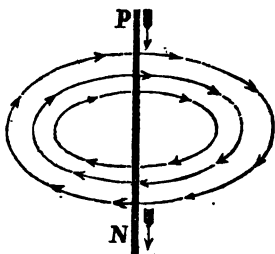
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ducting wire made to pass several times around the lower needle? What is such an instrument called?

167. What is the real motion that the current tends to produce in each pole of the needle? What is the force which produces

depend upon the mode in which it is supported, as well as the position of the wire in reference to it.

If we suppose the conducting wire to be placed in a vertical position, and the current of positive electricity to be descending through it, the tendency of a north pole in the vicinity of the wire will be to move around it in a horizontal circle, in the direction indicated by the arrows in the figure, or in the direction of the hands



of a watch with the dial upward. The tendency of the south pole would be to revolve in the opposite direction. If the direction of the electrical current is reversed, and made to pass upward, both poles would tend to revolve in the opposite direction from that described above. Whatever may be the position of the conducting wire with reference to the needle, the motions produced will always be in accordance with these principles.

It requires no reflection to perceive that, if the pole of a magnetic needle tends to revolve around a fixed conducting wire, a free wire will have a tendency to revolve around the pole of a fixed needle.

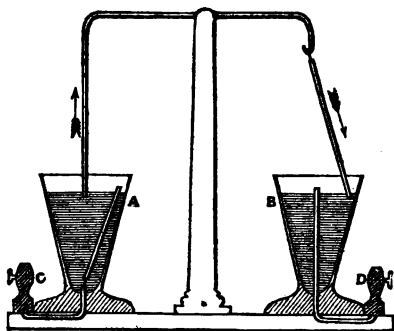
168. Both the revolution of a pole around a fixed wire, and the revolution of a wire around a fixed pole, may be shown by the apparatus, a section of which is seen in the cut at the top of the next page. A and B are two glass vessels, filled nearly to the top with mercury. A wire, supported by a pillar between the vessels, has one end bent

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this motion called? Suppose the current to be descending on a wire held perpendicularly near the north pole of a needle, in what direction does it tend to move around it? If the pole is fixed, does the conducting wire tend to move around it?

168. May both these motions be shown experimentally?





down so as to dip into the mercury in A; and the other end is bent into a hook, on which a short piece of wire is suspended, so that its lower end shall also dip into the mercury in the vessel B. Conducting wires pass through the bottoms of both vessels, with binding screws, CD, to connect them with the poles of the battery; and to that in A, a small magnet is attached by a thread, so that one of its poles may be a little above the surface of the mercury; and in the vessel B another small magnet is firmly fixed, with one pole a little above the mercury. When the current is passed through this apparatus, as indicated by the arrows, the upper pole of the magnet in A will revolve slowly around the conducting wire, and the free conducting wire suspended in B will revolve around the fixed pole near it.

169. *Magnetism of the Conducting Wire.*—The conducting wire, while the current is passing, readily attracts iron filings; but if it is bent into a coil or helix, and a magnet brought near it, the attractions and repulsions, precisely like those of two magnets, are at once seen.

Two wires, on which the current is passing in the same direction, are attracted in the same manner as unlike poles of two magnets; if the current is passing in opposite directions, they are repelled.

*De la Rive's Ring* is a beautiful contrivance to show the

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169. How is it shown that the wire becomes magnetic while the fluid is passing? Describe De la Rive's ring. What may

attractions and repulsions of a current by the poles of a magnet. A copper wire is bent into a circle about an inch in diameter, and the two ends passed through a piece of wood or cork, and soldered, one to a slip of zinc, Z, and the other to a slip of copper, C. If, now, it



be placed in a bowl of water containing a little acid, a current of electricity will circulate along the wire, in the direction of the arrows; and if a bar magnet be brought near it, it will be attracted or repelled, according as one pole or the other of the magnet is presented to it. As represented in the figure, if the north pole of the magnet is presented to it, it will be attracted; the south pole will first repel it, but in a little time it will turn around, and will then be attracted. We may, therefore, properly regard it as a flat magnet, having its two poles in the centre of the circle, the one on one side, and the other on the other; the *south pole* being in that surface on which, when held before you, the positive current flows in the direction of the hands of a watch. The apparatus will be more powerful if the conducting wire, covered with silk, to prevent lateral communication, be formed into several circles of the same diameter, on the principle of the multiplier. If the circle is made three or four inches in diameter, it will settle in a position facing the north and south; thus showing that it is influenced by the earth's magnetism, like the magnetic needle.

The effect will be still more decided, if the wire is bent in the form of a helix, four or five inches in length, and suspended in such a manner that it can move freely while the current is passing through it. The helix then strikingly

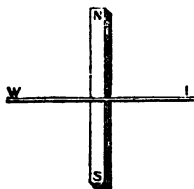
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we regard it? From what do all these motions necessarily result?

resembles a bar magnet, having its poles developed at its extremities.

All these motions result necessarily from the tangential force, as above (167) explained; and the intelligent student will seldom find a more interesting or instructive exercise than in tracing out the connections between them and this force. Our limits forbid our going more into details.

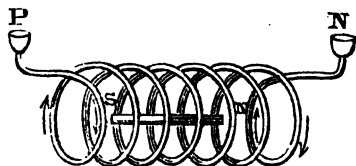
170. *Induction of Magnetism by a Current.*—Magnetism is induced in a small piece of soft iron by the simple passage of a current near it, in a direction at right angles to it.



Thus, if WI be the conducting wire, and NS a small piece of iron lying under the wire, while the current is passing, magnetic polarity will be induced in the iron, N being a north pole, and S a south pole, when the current passes from W to I; but if the current pass from I to

W, the poles will be reversed.

But, if the wire is made to pass around the iron many times, the effect will be greatly increased.) This is accomplished by placing the iron in a helix of wire, as shown in the figure. The current being then made to pass in the direction of the arrows, the



iron becomes strongly magnetic, with its poles as shown by the letters N and S. The cups P and N serve to connect it with the battery. When the current is broken, the iron ceases at once to be magnetic; but if a piece of hardened

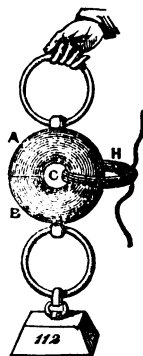
170. By what simple mode may magnetism be developed in a small piece of iron by a current? What will be the effect of winding the wire several times around the iron? What is the effect when the current is broken? What is a magnet produced in this manner called? Have they been made of great power?

steel be substituted for the iron, it retains its magnetism permanently.

A magnet formed in this manner, by the passage of a current of electricity around it, is very properly termed an *electro-magnet*. Magnets of this kind have sometimes been made of sufficient strength to sustain a weight of 2000, or even 3000 pounds. For this purpose, a bar of iron of considerable size is bent in the form of a horse-shoe, and the conducting wire made to pass many times around it, as represented in the figure. An armature of soft iron (161) is attached to the poles, as with the common magnet, from which the weights are suspended. As stated above, when the current of electricity is interrupted, the magnetism will be immediately destroyed, and the weights drop off.



171. *The Magic Circle*, as it has been termed, possesses too much interest to be here omitted, though no new principle is developed by its action. Two semicircles, A and B, are made of a stout bar of soft iron, and well fitted together, so as to form a circle, C, and include a small helix of wire, H, the two ends of which are to be connected with the electrodes of a small but active battery. While the current is passing, the semicircles are made powerfully magnetic, and will adhere with a force which is capable of sustaining a weight of many pounds.

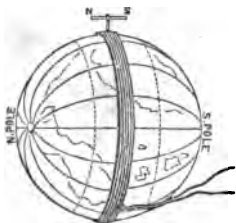


The wire used in all these arrangements is supposed to be wound with some insulating substance, as silk or cotton, to prevent the contact of the separate coils,

171. Describe the magic circle. Why is the conducting wire, used in these experiments, covered with silk or cotton?

which would permit a lateral discharge of the current, so that it would not pass around the whole length of the wire.)

172. *Magnetism of the Earth.*—We have seen above (164) that the earth may be considered as a great magnet, having its south pole somewhere near its north geographical pole, and its north pole near its south geographical pole; and it has been suggested that this may be occasioned by currents of electricity flowing around it, beneath its surface, from east to west, or in the direction opposite to that of its motion on its axis. Indeed, it has even been suggested that these currents may have their origin in the heating influence of the sun's rays, as successive portions of the earth's surface come under their influence by its daily motion; but this is to be regarded as only plausible conjecture. That the needle would be influenced by such a current, precisely as it really is, at different points of the earth's surface, may be shown



by winding a covered wire several times around the equator of a common globe, and placing a small magnetic needle upon it while the current is passing, as shown in the figure.

### 173. *Electro-Magnetic Engines.*

—All the above motions, it will be observed, whether of the magnetic needle or of the conducting wire, have been produced by the tangential force; but various machines have been devised, called electro-magnetic engines, for producing motion by the direct influence of pole upon pole of magnets, one of which, at least, must be that of an electro-magnet. Numerous machines of this kind

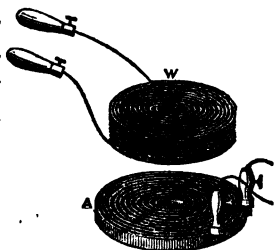
172. Where is the south magnetic pole of the earth situated? How may the polarity of the earth be occasioned? In what mode may this current in the earth be generated?

173. What is an electro-magnetic engine? Have such instruments been applied to any practical purpose?

have been constructed, capable of producing rapid rotary motion; but it has not yet been found practicable to adapt them for any useful purpose.

174. *Induction of a Current by a Current.*—If the conducting wire of a galvanic battery is made of considerable length, and another wire is placed by its side, parallel to it, having its two ends bent around, so as to come in contact, when the circuit of the battery is closed, a secondary current will be induced in the wire, flowing in the opposite direction to that of the battery or primary current; and on breaking the battery circuit, another secondary current will flow through the wire, in the same direction as the battery current.)

This is best shown experimentally in the following manner:—Let A be a coil of large copper wire, or, better, of copper ribbon, covered with some non-conducting substance, and having binding screws attached to each end, to receive the polar wires of the battery. Above this is placed a coil, W, of fine covered wire, with a handle at each end; and when the battery current is made to pass through the lower coil, another, called a secondary current, will be induced in the upper coil, as will be plainly indicated by grasping the handles with the moist hands. But it is to be observed that the duration of this secondary current is only momentary, and ceases at once, though the battery current be continued. When, however, the battery



174. Describe the mode of inducing a secondary current by means of the current of a battery. In what direction does the secondary current flow, when the battery current commences in the lower or ribbon coil? In what direction when it ceases?

current is discontinued, another secondary current is induced in the wire coil, which flows in the same direction as the battery current, as above stated. It is evident, therefore, that the effect of the shocks will be increased by rapidly breaking and closing the battery circuit, the feeble intensity of the shocks being compensated by their frequency.

By arrangements altogether similar to the above, with additional coils, *tertiary* currents have been produced, and others of still higher orders, even up to the seventh.

175. *Induction of Electricity by Magnetism.*—*Magneto-Electricity.*—Magneto-electricity, as the term implies, is the reverse of electro-magnetism. The current of galvanic electricity circulating around a bar of soft iron, converts it, as we have seen, into a temporary magnet, and renders a bar of steel permanently magnetic. Now, *a priori*, it would seem very probable that a magnet placed in the centre of a helix or spiral of metallic wire, would develop in it a current of electricity. This is found to be actually the case; but the current can be observed only at the moment of inserting the magnet or removing it.



The development of electricity by magnetism is shown in a very simple manner, by winding the middle of the keeper or armature AB, in the figure in the margin, of a powerful horse-shoe magnet, with copper wire, properly bound, and bringing the two extremities of the wire into contact, one of which should be flattened a little, and amalgamated by dipping it into a solution of nitrate of mercury, and the other filed to a point. If, now, the armature be suddenly placed upon the magnet or removed from it, a spark of elec-

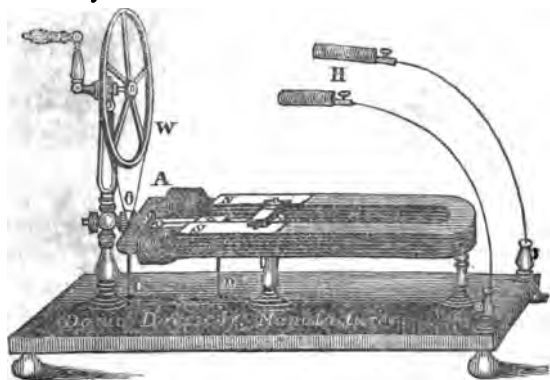
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175. What is magneto-electricity? Describe the mode of deve

tricity will manifest itself every time, at the point of contact, C, of the two extremities of the wire.

The electric current flows in one direction at the moment magnetism is induced in the soft iron enclosed in the coil of wire, and in the other direction, when its magnetism is destroyed.

Magneto-electric machines are now made, which act with great energy, producing all the effects both of quantity (145) and intensity.



The above figure, from Davis's excellent "Manual," represents a machine of this kind, called a magneto-electric machine. Several steel magnets, NS, are firmly fixed together upon pillars on a base board; and in front of the poles, a soft armature, A, in the form of the letter U, having its two arms wound with 2000 or 3000 feet of fine insulated wire, is made to revolve on an axis by means of the multiplying wheel W. As the armature is made to revolve in front of the strong poles of the fixed magnets, magnetism is induced in it (175), currents of electricity being at the same time

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loping a small spark of electricity by means of a strong magnet. Describe the magneto-electric machine.



made to flow through the coils of wire wound upon its arms, in accordance with the principles just explained, which are communicated by wires, concealed under the base board, to the metallic handles, H, by the wires CD. The arrangement by which the current is received from the coils upon the armature, is very complicated, and can be but imperfectly represented in a figure; and the inexperienced student will generally find it impossible to obtain a clear understanding of it, without having the machine before him.

176. *The Electro-Magnetic Telegraph.*—This is an instrument for conveying intelligence instantaneously, by means of the galvanic current, to any distance, where metallic wires can be extended and properly secured.

We have seen above (170), that the current, when made to pass around pieces of soft iron, renders them magnetic while the current is passing, but that they lose their magnetism instantly when the current is interrupted. Usually, the experiment is performed with the battery and the piece of iron in the same room, and even upon the same table, but this is not necessary. If the battery be in one room, and the piece of iron in another room, or in another building at a distance, the result will be the same, only a little increase in the power of the battery will be necessary. All that is required is, that good conducting wires, well insulated, should extend from the battery and form a helix around the iron, and on closing the circuit, whatever may be the distance of the iron from the battery, it instantly becomes magnetic, and loses its magnetism again when the circuit is broken. The closing and breaking of the circuit can be performed at any point in the line, but we suppose it to be done at the battery. Thus closing and opening the circuit, connected with a

176. How may a piece of soft iron be rendered magnetic at a great distance from the battery? May the current be made to produce a system of marks at a distance, without the aid of a magnet?

magnet that acts upon the proper machinery, systems of arbitrary marks, and even the letters of the alphabet, may be instantaneously formed, by various modes, at any distance from the operator, and intelligence thus conveyed. A full description of Morse's electro-magnetic telegraph is given in the author's larger work (edition of 1849), page 111. Indeed, the current may be made to act directly upon prepared paper at a distance, to produce a system of marks, without the aid of a magnet. This is understood to be the mode adopted by Mr. Bain in his telegraph, which has been recently patented in this country.

## PART II.

### PHILOSOPHY OF CHEMISTRY.

#### ELEMENTS—CHEMICAL AFFINITY—CIRCUMSTANCES MODIFYING THE ACTION OF AFFINITY.

177. *Elements*.—It has been stated that we consider all substances as simple, or elementary, that have not been decomposed. Of the exact number of these we cannot speak with certainty, as the existence of two or three, the discovery of which has been announced, has not yet been sufficiently verified. The number included in our table, on a succeeding page, is fifty-six; but of two of these, little comparatively is known. Besides these, there are at least three others, the existence of which, it is claimed, has been determined; but so little is known of them, if even the fact of their existence has been proved, that they are not considered as entitled to a place on our list.

178. The elementary substances are usually divided into the two classes of non-metallic and metallic, thirteen being included in the former, and the remainder in the latter class; but several of each class possess characters so peculiar, that it is difficult to assign them their proper place.

179. *Affinity*.—Affinity, or chemical attraction, has already been mentioned as one of the forces with which the

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177. What is the number of simple substances known? Have others been discovered?

178. Into what two classes are the elementary substances usually divided?

179. To the action of what force are all chemical changes to be

particles of every kind of matter seem to be naturally endowed. It is to the action of this force that all chemical changes, and the accompanying phenomena, are to be attributed. If two elements unite to form a compound, it is this force which occasions it; and if a compound of two or more substances, already formed, is destroyed by the action of another element, it is to this force we are to look for the cause of the change.

Affinity is exerted only between the minutest particles of different kinds of matter, causing them to combine so as to form new bodies, endowed with new properties. It acts only at insensible distances; in other words, apparent contact, or the closest proximity, is necessary to its action. Every thing which prevents such contiguity is an obstacle to combination; and any force which increases the distance between particles already combined, tends to separate them permanently from each other. It follows, therefore, that, though affinity is regarded as a specific power, distinct from the other forces which act on matter, its action may be promoted, modified, or counteracted by them; and, consequently, in studying the phenomena produced by affinity, it is necessary to inquire into the conditions that influence its operation.

180. The most simple instance of the exercise of chemical attraction is afforded by the admixture of two substances. Water and sulphuric acid, or water and alcohol, combine readily. On the contrary, water shows little disposition to unite with sulphuric ether, and still less with oil; for, however intimately their particles may be mixed together, they are no sooner left at rest than the ether separates almost entirely from the water, and a total separation takes place be-

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attributed? Between what only is affinity exerted? At what distance only does it act? May the action of affinity be counteracted or modified by other forces?

180. What simple instance of the action of affinity is mentioned?

tween that fluid and the oil. Sugar dissolves very sparingly in alcohol, but to any extent in water; while camphor is dissolved in a very small degree by water, and abundantly by alcohol. It appears, from these examples, that chemical attraction is exerted between different bodies with different degrees of force. There is sometimes no proof of its existence; between some substances it acts very feebly, and between others with great energy.

181. *Affinity is therefore said to be elective*, as, when several substances, capable of combining, are mixed together, a particular compound is always formed, in preference to others. Thus, if sulphuric acid, soda, and lime are at any time mixed together, the acid will always combine with the lime, in preference to the soda.

182. *Decomposition* of a compound is often effected by presenting to it a third substance, having a stronger affinity for one of the ingredients of the compound than those ingredients have for each other. Thus, oil has an affinity for the volatile alkali, ammonia, and will unite with it, forming a soapy substance called a liniment. But the ammonia has a still greater attraction for sulphuric acid; and hence, if this acid be added to the liniment, the alkali will quit the oil, and unite by preference with the acid. If water be poured into a solution of camphor in alcohol, the camphor will be set free, because the alcohol combines with the water. Sulphuric acid, in like manner, separates baryta from nitric acid. Combination and decomposition occur in each of these cases;—combination of sulphuric acid with ammonia, of water with alcohol, and of baryta with sulphuric acid;—decom-

Why does sugar dissolve more readily in water than in alcohol?  
 Why does camphor dissolve more readily in alcohol than in water?

181. Why is affinity said to be elective?

182. How is the decomposition of a compound often effected?  
 What will be the effect of pouring water into a solution of camphor in alcohol? How is this result explained? What will be

position of the compounds formed of oil and ammonia, of alcohol and camphor, and of nitric acid and baryta.

The action becomes more complex when two compounds are presented to each other, of such a nature that a transfer of elements takes place between them. Thus, in mixing together a solution of carbonate of ammonia, and another of hydrochlorate of lime, the carbonic acid of the first compound unites with the lime of the second, while the hydrochloric acid of the second combines with the ammonia of the first.

183. *Circumstances which modify the Action of Affinity.*—These are numerous, and a few only will be mentioned. The most important, probably, is the state, or form, of the substances; that is, whether it be solid, liquid, or gaseous. It is very rarely the case that two solids are capable of combining, unless one of them at least is first made liquid, either by solution in some solvent, or by melting. Thus, tartaric acid and carbonate of soda, in a dry state, are kept together for any length of time, without any action taking place between them; but if a little water be added to dissolve them, chemical action at once ensues, attended with violent effervescence.} Phosphorus and iodine, though both are solids, and phosphorus and sulphur, will indeed combine when brought together in their ordinary state; but even in these cases, one or both of the substances are made liquid during the action.

184. *Cohesion* (for it is this force which unites the particles of a solid) is therefore always opposed to the action of affinity; and whatever tends to diminish it in bodies capable

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the result when solutions of carbonate of ammonia and hydrochlorate of lime are mixed?

183. What is probably the most important circumstance that modifies the action of affinity? Are two solids usually capable of acting upon each other? What is said of tartaric acid and carbonate of soda? What is said in this connection of phosphorus and iodine?

184. Is cohesion always opposed to the action of affinity? Why

of acting upon each other, facilitates their union: Heated water is therefore usually a more powerful solvent than when cold; and salt in fine powder will be dissolved more rapidly in water, than when in large lumps.

185. *The gaseous state* is also unfavorable; to the action of affinity. Gases do indeed, in some cases, combine spontaneously, but, usually, the introduction of an ignited body, the electric spark, or, in some cases, the influence of the sun's rays, is needed to cause the action to commence. Thus, a mixture of oxygen and hydrogen may be kept for any length of time; but the introduction of flame, or the passage of the smallest spark of electricity, will cause them to combine instantly, with a powerful explosion.

186. *Contact with a third body* sometimes will cause a union of two elements, that would otherwise remain together without combining. Thus, the introduction of a piece of spongy platinum into a mixture of oxygen and hydrogen, produces an explosion in a few seconds, without any change being produced in the metal, except that it becomes intensely heated. This power of some bodies to produce chemical changes, merely by their presence, is termed *catalysis* (from the Greek *kata*, by, and *luo*, to unloose).

187. *Mechanical action* also favors the action of affinity. Thus, if a piece of phosphorus be wrapped, with a few crystals of chlorate of potash, in a piece of tin foil or strong paper, a smart blow will cause a violent explosion. Common friction matches are ignited by friction against sand-paper, or other hard substance.

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is salt or other substance more rapidly dissolved in warm than in cold water?

185. Is the gaseous state favorable or unfavorable to chemical action? Do gases sometimes combine spontaneously? Is this usually the case?

186. What is said in this connection of contact with a third body?

187. How may a piece of phosphorus be inflamed in contact with crystals of chlorate of potash?

188. *Relative quantity of matter* is the last circumstance we mention, as affecting the action of this force. What is meant by this may be illustrated by the solution of common salt in water. If equal quantities of the salt are added in succession to the water, the first portion will disappear in less time than the second, the second in less time than the third, and so on. As the relative quantity of salt contained in solution increases, the action of the water becomes enfeebled, until full saturation takes place. If a large quantity of salt had been added at first, the full saturation of the water would have taken place much more speedily.

189. *Changes that accompany the Action of Affinity.*—A change of properties, to a greater or less extent, always attends chemical action; but no means are yet known by which we can predict what any of these changes will be in any case, previous to making the trial.

Often, when two bodies unite, the characteristic properties of both will disappear, and the bodies are said to *neutralize* each other. Thus, the acids are usually sour to the taste, and possess the power of changing the blue color of some vegetables to red; while the alkalies are exceedingly caustic to the taste, and change vegetable blues to green. Now, when an acid and an alkali unite, a new substance is formed, called a salt, which is mild to the taste, and produces no effect whatever upon vegetable colors; and, indeed, while it possesses many new properties of its own, exhibits none of those of either of its ingredients.

This change may extend to any or all of the properties

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188. If several equal small portions of salt be added successively to a portion of water, which portion of salt will be soonest dissolved? What reason is given?

189. Does any essential change of properties take place in bodies when they unite? When are two substances said to neutralize each other? How is this illustrated by reference to an acid and an alkali? May the change extend to all the properties of a body?



of bodies. (1.) Bodies, after combining, do not usually occupy the same space they did before combination. Generally, a contraction of volume takes place, but this is not universal. A pint of water, added to a pint of sulphuric acid, will not produce a quart of the mixture; and the same will be found true of water and alcohol. When two gases combine, a very great contraction often takes place; but the result with different gases is very different. (2.) The changes of form that attend chemical action are exceedingly various. The combination of gases may give rise to a liquid, as in the union of oxygen and hydrogen to form water; or to a solid, as in the union of carbonic acid gas and ammonia to form solid carbonate of ammonia; or hydrochloric acid and ammonia, to form hydrochlorate of ammonia. Two solids may, in combining, form a liquid, as is the case when crystals of sulphate of soda and nitrate of ammonia are rubbed together in a mortar, or acetate of lead and alum. Solids may also, in combining, form gases, as is the case when gunpowder detonates. Two liquids, by uniting, may form a solid, as may be shown by pouring sulphuric acid into a solution of hydrochlorate of lime. (3.) Chemical action is frequently attended by change of color. No uniform relation has been traced between the color of a compound and that of its elements. Iodine, whose vapor is of a violet hue, forms a beautiful red compound with mercury, and a yellow one with lead. The black oxide of copper generally gives rise to green and blue-colored salts; while the salts of the oxide of lead, which is itself yellow, are for the most part colorless.

A beautiful instance of the change of color produced by

Will a pint of water, added to a pint of sulphuric acid, produce a quart of the mixture? When two gases unite, may a liquid or a solid be formed? What will be the result when crystals of nitrate of ammonia and sulphate of soda are rubbed together? May great change of color be produced by chemical action?

chemical action is seen in mixing solutions of bichloride of mercury and iodide of potassium. The solutions may be made as perfectly limpid as water, but, upon being mixed, a beautiful vermilion red is produced, by the formation of biniodide of mercury. The color shortly disappears, if either solution was in excess, by the redissolving of the precipitate.

#### LAWS OF COMBINATION.—ATOMIC THEORY.

190. *Laws of Combination.*—The relative proportion in which substances unite to form the different compounds, is governed by fixed laws. There are, however, some apparent exceptions to this rule, in which bodies seem to unite in all proportions, without reference to any law. Thus, water and alcohol seem to unite in all proportions; and the same may be said of water and the liquid acids. There are still other substances which seem to combine in any proportion within certain limits. Thus, water dissolves common salt very readily, but the quantity it is capable of holding in solution cannot exceed about four-tenths of its own weight. Below this limit, the water and salt appear to unite in every proportion.

In all such cases, the substances are held together by a very feeble affinity, and are therefore easily separated.

But the most interesting series of compounds is produced by substances which unite in a few proportions only, and which, in combining, lose more or less completely the properties that distinguish them when separate. Of these bodies, some form but a single compound, while others unite in two, and some in three, four, five, or more proportions.

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190. Are the relative proportions in which bodies combine governed by fixed laws? Are there some apparent exceptions to the rule? What is said of common salt and water in this connection? In such cases, are the substances united by a strong affinity?

191. The following are the laws which regulate the composition of such compounds:—

- I. *The composition and properties of compound bodies are unchangeable.*

By this it is meant (1.) that any compound, while it retains its characteristic properties, must contain the same elements, united in the same proportions; and (2.) that while a compound contains the same elements, united in the same proportion, it must also possess the same characteristic properties. Thus, water, a compound of 1 part\* of hydrogen and 8 parts of oxygen, possesses certain well-known properties; now, whenever and wherever a substance is found, possessing the various properties of water, we know, from this law, that it must be a compound of these two substances, united in the above proportion; and whenever a compound of these substances, in this proportion, is formed, it must possess the peculiar properties of water.

A change of properties always necessarily implies a change of composition; and, conversely, a change of composition necessarily implies a change of properties. This law is of universal application, except in the case of isomeric compounds, which will be hereafter noticed.

- II. *When any substances (as B, C, D, &c.) combine with a given quantity of another substance (A), then the numbers which represent the proportions in which B, C, D, &c., combine with A, will also represent the proportions in which they will combine with each other, if such combination be possible.*

This law is also of universal application, and examples to illustrate it are abundant. Thus,

\* Parts by weight are always intended, unless it is otherwise expressed.

191. How is the first law of combination stated? How is it illustrated? Does a change of properties necessarily imply a change of composition? How is the second law of combination

|        |                 |                                    |
|--------|-----------------|------------------------------------|
| 8.01   | parts of oxygen | } combine with 1 part of hydrogen. |
| 35.47  | " " chlorine    |                                    |
| 16.12  | " " sulphur     |                                    |
| 126.57 | " " iodine      |                                    |
| 78.39  | " " bromine     |                                    |

It follows, therefore, that if oxygen and chlorine combine, it will be in the ratio of 8.00 parts of the former to 35.47 parts of the latter; and if chlorine and iodine combine, the compound will contain 35.47 parts of the former, and 126.57 parts of the latter; and so of the other substances mentioned.

Any other substance, having an extensive range of affinity, might also be selected as the basis of our table, and tables be formed of all known substances. The numbers thus obtained for the various substances are called their *combining numbers*, or *equivalents*. It will be noticed that the numbers used merely express the relative quantities of the substances they represent, that combine together; it is therefore in itself immaterial what figures are employed to express them. The only essential point is, that the relation should be strictly observed. Thus, the equivalent of hydrogen may be assumed as 10; but then the number for oxygen will be 80.1; that for chlorine 354.7, &c. Hydrogen combines with other bodies in a lower proportion than any other known substance, and is therefore, with propriety, made the unit by most writers in the English language; but on the continent of Europe, oxygen is usually considered as 100, and the tables constructed accordingly.

192. We give below a table of all the known elementary substances, with their combining numbers, or equivalents,

stated? How is it illustrated by several substances which combine with hydrogen? Do the numbers used express the absolute quantities that combine, or only the proportions? What are these numbers called? Why is the number for hydrogen called 1? What is sometimes made the number for oxygen?

192. How may the numbers in the table be converted into others, having oxygen = 100 for their basis? How is the third law of

the combining weight of hydrogen being considered as the unit. To find the corresponding numbers in a table in which the combining weight of oxygen is made 100, it is only necessary to multiply the numbers in this table by 12.48. We insert also, in the table, the symbols by which the elements are represented in chemical formulæ, a subject to which the attention of the student will be called in a future paragraph.

In subsequent parts of this work, the word atom is often used as synonymous with equivalent or combining proportion.

TABLE OF ELEMENTS, WITH THEIR EQUIVALENTS AND SYMBOLS.

| Elements.             | Sym-<br>bols. | EQUIVA-<br>LENTS. | Elements.              | Sym-<br>bols. | EQUIVA-<br>LENTS. |
|-----------------------|---------------|-------------------|------------------------|---------------|-------------------|
| Aluminum.....         | Al            | 13.72             | Manganese.....         | Mn            | 27.72             |
| Antimony (Stibium) .. | Sh            | 129.24            | Mercury (Hydrargyrum)  | Hg            | 202.87            |
| Arsenic.....          | As            | 75.34             | Molybdenum.....        | Mo            | 47.96             |
| Barium.....           | Ba            | 68.66             | Nickel.....            | Ni            | 29.62             |
| Bismuth.....          | Bi            | 71.07             | Nitrogen.....          | N             | 14.15             |
| Boron.....            | B             | 10.91             | Osmium.....            | Os            | 99.72             |
| Bromine.....          | Br            | 78.39             | Oxygen.....            | O             | 8.01              |
| Cadmium.....          | Cd            | 55.83             | Palladium.....         | Pd            | 53.36             |
| Calcium.....          | Ca            | 20.52             | Phosphorus.....        | P             | 31.44             |
| Carbon.....           | C             | 6.12              | Platinum.....          | Pt            | 98.84             |
| Cerium.....           | Ce            | 46.05             | Potassium (Kalium).... | K             | 39.26             |
| Chlorine.....         | Cl            | 35.47             | Rhodium.....           | R             | 52.20             |
| Chromium.....         | Cr            | 28.19             | Selenium.....          | Se            | 39.62             |
| Cobalt.....           | Co            | 29.57             | Silicon.....           | Si            | 22.22             |
| Columbium (Tantalum)  | Ta            | 184.90            | Silver (Argentum)..... | Ag            | 108.30            |
| Copper (Cuprum).....  | Cu            | 31.71             | Sodium (Natrium).....  | Na            | 23.31             |
| Didymium.....         | Di            |                   | Strontium.....         | Sr            | 43.85             |
| Fluorine.....         | F             | 18.74             | Sulphur.....           | S             | 16.12             |
| Glucinum.....         | G             | 26.54             | Tellurium.....         | Te            | 64.25             |
| Gold (Aurum).....     | Au            | 199.20            | Thorium.....           | Th            | 59.83             |
| Hydrogen.....         | H             | 1.00              | Tin (Stannum).....     | Sa            | 58.92             |
| Iodine.....           | I             | 126.57            | Titanium.....          | Ti            | 24.33             |
| Iridium.....          | Ir            | 98.84             | Tungsten (Wolfram) ..  | W             | 94.80             |
| Iron (Ferrum).....    | Fe            | 27.18             | Vanadium.....          | V             | 68.66             |
| Lanthanum.....        | La            |                   | Uranium.....           | U             | 217.26            |
| Lead (Plumbum).....   | Pb            | 103.73            | Yttrium.....           | Y             | 32.25             |
| Lithium.....          | L             | 6.44              | Zinc.....              | Zn            | 32.31             |
| Magnesium.....        | Mg            | 12.69             | Zirconium.....         | Zr            | 33.67             |

III. *When two substances combine in more proportions than one, then these different proportions will always sustain some simple ratio to each other.*

To illustrate this law, let us suppose that A and B are the

two substances; if they combine in one proportion only, it will usually be in the ratio of one equivalent of A to one equivalent of B; but if they combine in more proportions than one, it will be in the ratio of one equivalent of A to two, three, or four equivalents of B; or one equivalent of B to two, three, or four equivalents of A. They may, however, combine (and instances of this kind are not unfrequent) in the ratio of two equivalents of A to three, five, or seven equivalents of B; or two equivalents of B to three, five, or seven of A. Still more complex ratios are sometimes met with, as compounds in which three equivalents of one substance combine with four or five of the other; but such cases are rare.

The compounds of nitrogen and oxygen afford an excellent illustration of the above law. Thus, the

|                                                          |   |   |              |            |
|----------------------------------------------------------|---|---|--------------|------------|
| 1st compound contains—Nitrogen, 14.15, and Oxygen, 8.01. |   |   |              |            |
| 2d                                                       | " | " | Do. 14.15, " | Do. 16.02. |
| 3d                                                       | " | " | Do. 14.15, " | Do. 24.03. |
| 4th                                                      | " | " | Do. 14.15, " | Do. 32.04. |
| 5th                                                      | " | " | Do. 14.15, " | Do. 40.05. |

IV. *The equivalent of a compound substance will always be equal to the sum of the equivalents of the substances which compose it.*

Thus, water is composed of one equivalent of oxygen (8.01) and one equivalent of hydrogen (1); its combining number, or equivalent, will therefore be  $(8.01 + 1 =) 9.01$ . So, also, sulphuric acid, which contains one equivalent of sulphur (16.12) and three equivalents of oxygen ( $8.01 \times 3 = 24.03$ ), has for its equivalent 40.15. The same is true of all compound bodies.

In the above, and also in the table, page 130, the decimals are carried to two places; but in general, hereafter, they will

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combination stated? How is it illustrated? How by reference to the compounds of nitrogen and oxygen? How is the fourth law of combination stated? How is it illustrated in reference to the

be carried only to tenths, which will be sufficiently accurate for our purpose.

V. *The quantities of gaseous substances, estimated by measure, which enter into combination, bear some simple ratio to each other.*

Water, we have seen, is composed of one equivalent (estimated by weight) of each of its elements, hydrogen and oxygen, which are gases; but if we measure them before causing them to combine, we shall find that one pint of oxygen will unite with exactly two pints of hydrogen. If we use more oxygen than this in proportion, a part of it will remain after combination; and if we use less, a part of the hydrogen will be left.

So, a pint of chlorine will combine with exactly a pint of hydrogen, and a pint of nitrogen with exactly three pints of hydrogen. But it is to be observed in these cases, that, in combining, considerable contraction often takes place, so that the measure or volume of the compound formed will not always be equal to the sum of the volumes of the gases that have combined. Thus, the pint of oxygen and two pints of hydrogen will form only two pints of the vapor of water; and the pint of nitrogen and three pints of hydrogen will form only two pints (not four pints, as we might suppose) of the compound gas, which is called ammonia.

In the five compounds of nitrogen and oxygen contained in the above table, just two volumes of nitrogen are combined successively with one, two, three, four, or five volumes of oxygen.

193. *Atomic Theory.*—It will be observed that nothing theoretical pertains to the above laws, which are simply the

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composition of water? What is the fifth law of combination? In what ratio, by measure, do the gases oxygen and hydrogen combine to form water? Can they be made to unite in any other proportion?

193. What is the design of the atomic theory? What does it

enunciation of well-determined facts; but such striking results, obtained by experiment, naturally incline us to inquire for their cause; and, in the absence of positive proof, the atomic theory has been proposed for this purpose.

This theory assumes that every simple substance is an aggregation of atoms (9), by which is meant the particles in their smallest state of division; and that the atoms of the same substance are all precisely of the same weight. It assumes, also, that when simple substances combine to form compounds, they unite by atoms; that is, one atom of one substance combines with one, two, three, &c., atoms of the second; or two atoms of the first combine with three, five, or seven, &c., atoms of the second, &c. As these atoms are supposed to be absolutely indivisible, there can, of course, be no such thing as half an atom; and all compounds must be of the form  $1 A + 1 B$ ,  $1 A + 2 B$ ,  $2 A + 3 B$ , &c. The absolute weight of an atom of any substance has never been determined, but it is assumed that the equivalents of the various bodies do actually express their relative weights; the term *atomic weight* is therefore often used as synonymous with equivalent. Thus, the atomic weight of oxygen is said to be 8, and that of hydrogen, 1, &c.; and water is said to be a compound of one atom of oxygen and one atom of hydrogen; while sulphuric acid is a compound of one atom of sulphur and three atoms of oxygen.

If this theory be assumed as true (and it is considered very probable), but little reflection is needed to see that all the above laws, except, perhaps, the last, result from it as a matter of course; and further explanation would therefore be superfluous.

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assume? What does the atomic theory suppose to be true of the weight of all the particles of a substance? Has the absolute weight of the particles of any substance ever been determined?



## NOMENCLATURE OF CHEMISTRY—SYMBOLS.

194. *Nomenclature.*—Chemistry possesses a more systematic nomenclature than any other branch of natural science; and a thorough knowledge of it, at the very beginning of his studies, is very important to the student. This nomenclature is framed in reference to the composition of compounds, and is so contrived that the names of all compounds shall indicate the substances of which they are composed.

Elementary substances being composed of only one kind of particles, of course the above remark does not apply to them: their names are mere names; that is, mere sounds connected by usage with the things signified. Yet, in the case of newly discovered elements, names have in some instances been given that indicate some important property of the substance. Thus, oxygen (from the Greek *oxus*, acid, and *gennao*, to produce) was so named, because it was supposed to form a necessary part of all acids; and hydrogen (from *hudor*, water, and *gennao*), because it was known to enter into the composition of water. So chlorine, being of a greenish color, received its name, in consequence, from the Greek *chloros*, green; and bromine was so called from its offensive odor, from *bromos*, fetid. Potassium and sodium are so named, because they form the basis, respectively, of potassa and soda; and glucinum (from *glukus*, sweet), because of the sweet taste of some of its compounds. Other elementary substances of recent discovery have been named in like manner; but all simple substances which have been

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194. What is said of the nomenclature of chemistry? What does the name of a compound indicate in regard to it? Why was the name oxygen given to the substance known by it? What property of chlorine is indicated by its name?

long known retain their ancient names. Thus, gold, silver, lead, copper, sulphur, carbon, are names of well-known substances, and they are retained in chemistry; but they contain, it is evident, no descriptive meaning.

195. But it is to compound bodies that the nomenclature especially applies; and, as above intimated, its design is to indicate their composition by their names. For this purpose, when two substances only are combined in a compound, a part of the name of one, with the termination *ide* or *uret*, is made use of, while the other is expressed in full. Thus, oxygen forms oxides; chlorine, chlorides; bromine, bromides; sulphur, sulphurets; carbon, carburets, &c., of the other substance, the name of which is fully expressed; as oxide of iron, oxide of sulphur, chloride of hydrogen, &c. Usage requires us to employ the termination *ide* for the compounds of all the elementary substances except those of carbon, sulphur, and phosphorus, with which, without any apparent reason, we use the other termination, *uret*. Thus we say sulphuret of carbon, and not sulphide; phosphuret of calcium, and not phosphide or phosphuride.

When the elements unite in more than one proportion, numeral prefixes from the Greek or Latin are used to designate them; as protoxide of copper (from *protos*, first), and deutoxide (*deuteros*, second) or binoxide (*bis*, twice) of copper. The first of these compounds contains one equivalent of oxygen, united with one eq. of copper, while the second contains two eq. of oxygen, combined with one of copper. So the teroxide (*tertio*, third) or tritoxide (*tritos*, third) of

195. When two substances form a compound, how is the compound named? What are the compounds oxygen forms with other substances called? What is oxide of iron? Chloride of hydrogen? With the compounds of what substances do we use the termination *uret*? What is sulphuret of carbon? When the elements unite in more than one proportion, how are the different proportions expressed? What is protoxide of copper? Deuto or binoxide of copper? What is the tritoxide of nitrogen? How is the prefix

nitrogen, is a compound of three eq. of oxygen and one eq. of nitrogen. The same rule is observed with regard to the compounds of other substances, as protosulphuret and bisulphuret of mercury, bicarburet of sulphur, terchloride of gold, &c. The prefix *per* is often used to indicate the highest compound known, as peroxide of mercury; and the prefix *sesqui* implies that two eq. of one of the substances is combined with three eq. of the other substance; as sesquioxide of iron, which contains two eq. of iron and three eq. of oxygen. Generally, the electro-negative element is expressed first, as chloride of sulphur, and not sulphuret of chlorine; but this rule is not universally followed.

196. Most of the compounds above described, which may properly be called binary, or bielementary, as being composed of two elements, are also capable of combining together, and forming other more complex compounds, usually called salts. In considering the relations they sustain to each other, they are usually divided into the two classes of acids and bases. The acids are generally more or less sour to the taste, change vegetable blues to red, and are electro-negative in relation to the other class; while the bases are electro-positive, and restore the blue colors which have been changed to red by acids. Some of the bases are soluble in water, and are exceedingly acrid and caustic.

A large proportion of all the acids are oxides, and are therefore called oxygen acids, or oxyacids; but many contain hydrogen, and are called hydracids. So, when a sulphuret possesses acid properties, it is called a sulphur acid.

As most of the acids belong to the first class, or are oxy-

*per* used? What is sesquioxide of iron? Which element is usually named first?

196. Why may the compounds above described be called binary or bielementary? Into what two classes may they be divided? What is an acid? What a base? What is an oxyacid? What a hydracid? Why is special reference had, in forming the nomen-

acids, special reference is had to them in the nomenclature; and they are named by using the termination *ic* or *ous* in connection with the name of the substance with which the oxygen is combined to form the acid, the termination *ic* being used for the acid containing most oxygen, when there are more than one formed from the same substance, and the termination *ous* for the one containing least. Thus we have sulphuric and sulphurous acids, the former of which contains more oxygen, and is a more powerful acid than the latter. When there are more than two acids formed from the same substance, the prefix *hypo* (*hupo*, sub, or under) is used in connection with the name of one or the other of the two already described, as the case may require. Thus, we have four acids of sulphur, viz., the sulphuric, the *hyposulphuric*, containing less oxygen than the sulphuric, the sulphurous, and the *hyposulphurous*, which contains less oxygen than the sulphurous.

When a compound, not containing oxygen, possesses acid properties, a part of the name of one of the substances is used as a prefix to the name of the other substance, to form a name for the acid. Thus, hydrochloric and hydrosulphuric acids are compounds of hydrogen with chlorine and sulphur respectively. So chloriodic acid is a compound of (chlorine and iodine). If no prefix of the kind is used, the acid is understood to be an oxyacid, as nitric acid, which is composed of nitrogen and oxygen.

197. The salts are compounds of the acids with bases, as Glauber's salt (sulphate of soda), which is composed of sul-

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clature, to the oxyacids? How are the names of these acids formed? How are the terminations *ic* and *ous* used? How the prefix *hypo*? What is hyposulphuric acid? Hyposulphurous? When a compound, not containing oxygen, possesses acid properties, how is it named? What is the composition of hydrochloric acid? Chloriodic? What is to be understood when no prefix is used?

197. Of what are salts composed? How are the names of salts

phuric acid and soda. Names of the salts are formed by changing the termination of the name of the acid from *ic* into *ate*, and from *ous* into *ite*, and expressing in full the name of the base. Thus, sulphuric acid, combined with bases, forms *sulphates*; carbonic acid, *carbonates*, &c., of the bases with which they may be severally united; as *sulphate* of lime, *phosphate* of alumina, *hyposulphate* of soda, &c. So sulphurous acid forms *sulphites*; nitrous acid, *nitrites*; hyposulphurous acid, *hyposulphites*, &c., of the various bases.

Many of the metallic oxides serve as bases of salts, but in expressing them (the salts), the word oxide is often omitted; thus, sulphate of iron is the same as sulphate of the oxide of iron. If a higher oxide than the protoxide forms the base of a salt, it is usually expressed in full; thus, we have the sulphate, nitrate, &c., of the binoxide of mercury.

198. *Acid* or *super* salts are such as contain an excess of acid, while *basic* or *sub* salts contain an excess of base; salts that contain no excess of either acid or base being called *neutral salts*. A *bisulphate* contains twice, and a *tersulphate* three times as much acid as a sulphate. Prefixes derived from the Greek numerals are often used to express the excess of base in the subsalts; as *dinitrate* of lead, a salt which contains 1 equiv. of nitric acid and 2 equiv. of oxide of lead. The same thing would be expressed by calling it *bibasic nitrate* of lead.

The above explanations will serve to illustrate the fundamental principles of the present nomenclature; but it is

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formed? Of what is sulphate of lime composed? Phosphate of alumina? What name do salts formed by sulphurous acid take? Hyposulphurous acid? When a metallic oxide serves as the base of a salt, how is the name often expressed? Give an example. When the oxide is not a protoxide, how is it expressed?

198. What are acid or super salts? What are basic or sub salts? What is a neutral salt? What is said of the acid in a bisulphate? Tersulphate? Do the principles of the nomenclature apply to the more complex compounds?

admitted that it applies but partially to the more complex chemical compounds, which, however, are not of frequent occurrence.

199. *Chemical Symbols*.—Instead of writing the full name of substances, it is often convenient to substitute abbreviations, which are called the *symbols* of these substances. For a simple substance, the first letter of the Latin name is generally used; but when there are two or more having the same initials, some other letter of the name is connected with the initial, in the symbols of all except one. Thus, O stands for oxygen, and Os for osmium; B for boron, Bo for borium, and Bi for bismuth; P for phosphorus, Pd for palladium, and Pt for platinum, &c. In the table on page 130, the symbols in general use for all the simple substances are given.

These symbols indicate single equivalents of the substances they respectively represent; and to indicate two, three, or more equivalents, a figure is placed a little below the symbol at the right. For instance, S signifies a single eq. of sulphur, S<sub>2</sub>, S<sub>3</sub>, &c., two, three, &c., eq.; and O<sub>4</sub>, C<sub>5</sub>, four eq. of oxygen, five eq. of carbon, &c. To indicate that several substances are combined, their symbols are simply written side by side, as HO, or with a comma between them, as H,O, or with the plus sign (+), as H+O; all of which expressions represent a single equivalent of protoxide of hydrogen, or water. The comma and the plus sign are generally made use of only when the expression is somewhat complex; thus, NO<sub>5</sub> is the symbol for nitric acid, KO that for potassa, and NO<sub>5</sub>, KO, or NO<sub>5</sub>+KO, that of nitrate of potassa. Sometimes the plus sign is used when the substances be-

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199. For what purpose are chemical symbols used? What are the symbols of the simple substances? When two elements have the same initials, what course is pursued? What do these symbols indicate? What does a figure placed at the right of a symbol indicate? How is it indicated that several substances are combined? When are commas and when the plus sign used? What is to be

tween which it is placed are not combined, but only mixed.

It is to be particularly observed that small figures, placed at the right of letters, apply only to the ones to which they are attached; but large figures, placed at the left, like algebraic coefficients, affect all that follow them to the next comma or plus sign. Thus,  $\text{PO}_5$  represents phosphoric acid;  $\text{NaO}$ , soda;  $\text{NaO}, \text{PO}_5$ , phosphate of soda;  $2(\text{NaO}, \text{PO}_5)$ , two equivalents of the same phosphate of soda; but  $2\text{NaO}, \text{PO}_5$  indicates a single eq. of bibasic phosphate of soda, which contains two eq. of soda, united to one of acid.

In consequence of the frequent occurrence of the double equivalent, it is frequently expressed by drawing a line under the symbol of the single equivalent, or by a black letter. Thus,  $\text{Al}$  signifies an equiv. of aluminum, and  $\underline{\text{Al}}$  or  $\blacktriangle$ , two equivalents.  $\underline{\text{AlO}_3}$  or  $\blacktriangle\text{O}_3$  is the symbol for the sesquioxide of aluminum or alumina, and means the same as  $\text{Al}_2\text{O}_3$ . As oxygen forms an extensive list of compounds, simple dots are often used to indicate its presence in them; the above symbol for alumina would then become  $\blacktriangle = \text{Al}_2\text{O}_3$ . Other examples follow the same rule.

Combinations of these symbols, according to the principles above explained, are called *Chemical Formulæ*; and the great advantages of their use, in expressing forcibly complicated chemical changes, will be fully seen as we proceed.

200. *Isomerism*.—Isomeric compounds (191) are such as have the same ultimate composition, but differ from each other in some or all of their sensible properties. The term is derived from the Greek *isos*, equal, and *meros*, part.

These compounds, though composed of the same elements in the same proportion, have usually different equivalents; observed of large figures placed at the left of symbols? How are double equivalents often expressed? How is the presence of oxygen in compounds sometimes indicated?

200. What are isomeric compounds? How do the equivalents

thus, olefiant gas ( $C_2H_2$ ) and etherine  $C_4H_4$ ) are isomeric, being composed of carbon and hydrogen in the same proportion; but the equivalent of olefiant gas (14.24) is only half that of etherine (28.48).

Isomerism may also result from difference in the grouping or arrangement of the particles of compounds; thus, the particles of sulphuric acid ( $SO_3$ ) may be arranged in three modes, as  $SO_3$ ,  $SO + O_2$ , or  $SO_2 + O$ ; but we are entirely ignorant which is the actual arrangement in this well-known substance. Nitrate of ammonia ( $NH_3, NO_3$ ), when heated, becomes  $2NO + 3HO$ ; that is, an equivalent of the salt is changed into 2 eq. of binoxide of nitrogen, and 3 eq. of water. Change of grouping, therefore, may often produce important change of properties, while the ultimate composition remains the same.

201. *Allotropism*.—This term is used to designate the different conditions in which a substance is sometimes found, as it regards the chemical action of other bodies. Thus, iron, in its ordinary state, is readily dissolved by nitric acid; but if, before immersing a piece of iron wire in this acid, one end of it be heated to redness, or if it is connected with the positive electrode of a galvanic battery, or if it be immersed in the acid in contact with a piece of platinum,—in either of these cases, the acid fails to act upon it. So, if an aqueous solution of chlorine be prepared in the dark, it may be kept in a dark place without change for a long time; but if the sun is permitted to shine upon it a few seconds, decomposition will commence, hydrochloric acid will be formed in the water, and bubbles of oxygen rise to the surface.

Many other substances exhibit similar peculiarities, and are said to exist in different allotropic states.

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of two isomeric compounds generally differ from each other? Give an example. In what three different modes may the particles of sulphuric acid be grouped?

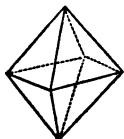
201. How is the term allotropism used? Give an example.



## CRYSTALOGRAPHY.

202. The particles of liquid and gaseous bodies, as they unite to form solids, sometimes cohere together in an indiscriminate manner, and give rise to irregular, shapeless masses; but more frequently they attach themselves to each other in a certain order, so as to constitute solids possessed of a regularly limited form. The process by which such a body is produced is called *crystalization*; the solid itself is termed a *crystal*; and the science, the object of which is to determine and classify the forms of crystals, is *crystallography*.

Nature presents us with an abundance of crystals in the mineral kingdom, but they may also be produced artificially by several processes. The essential condition is, that the particles of the substance to be crystalized should be free to move among each other, which is accomplished by bringing it into the liquid state by solution or by melting it. Alum

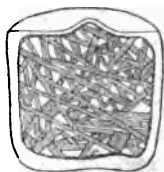


forms beautiful octohedral crystals, by making a saturated solution in warm water, and allowing it to cool slowly. If a small tree be made of copper wire, and its branches immersed in such a solution while cooling, on removing it, the part immersed will be covered with a multitude of small shining octohedrons, like fruit. If the solution be allowed to stand after it has become cold, the crystals will gradually increase in size as the water evaporates. Common salt, blue and green vitriol, and many other substances may be crystalized in a similar manner.

Crystalization by fusion is also very common. If a quantity of sulphur be melted and allowed to cool slowly, upon

202. How do the particles of bodies often unite together? What is a crystal? May crystals be produced artificially? How may alum be crystalized? How may sulphur be crystalized? Does crystalization sometimes take place solids?

breaking the crust and pouring out all that remains liquid, a mass of crystals will be found within, shooting in every direction, as represented in the figure.



The crystallization of many substances, as sulphur, corrosive sublimate, iodine, &c., may also be produced by sublimation.

Even in solids, crystallization sometimes takes place. Copper wire which has been long kept is said often to lose its tenacity, in consequence of cubic crystals of the metal gradually forming in it. When sugar is melted and allowed to cool, it forms a hard, transparent mass; but by keeping some time, it gradually becomes opaque, and exhibits the ordinary white color and crystalline structure of refined sugar. Common "lemon candy," which is usually sold in small flat pieces, an inch wide and four inches long, is beautifully transparent when first formed; but after a few hours, crystallization commences in numerous points, and gradually extends through the mass, which now becomes opaque; and at the same time its flavor is much improved. Many substances, in crystalizing, absorb a large quantity of water, called their *water of crystalization*, which is essential to the existence of the crystals. It sometimes amounts to half their weight. When exposed to the air, the water often evaporates, and the crystals fall to powder. They are then said to *effloresce*. Glauber's salt is a noted instance of this.

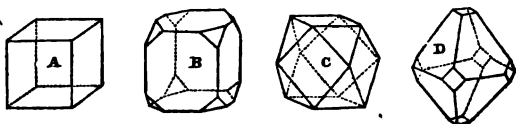
203. The forms of crystals are exceedingly diversified, but they may all be reduced to six systems or classes, and to fourteen forms, called *primary forms*. All other forms may be derived from these by regular process, and are therefore called *secondary forms*.

When a substance crystalizes, a very small crystal is first

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203. To how many systems may all the forms of crystals be reduced? How many primary forms are there? When a substance

formed, which gradually increases in size by the deposition of particles on every side; but sometimes, as the process is going on, a change in the deposit takes place, and regular spaces are left at the angles or edges, on which no deposit is made; and a secondary form then results. This is illustrated by the accompanying figures. We will suppose some



substance is crystalizing (as common salt), the primary form of which is a cube, as A. From some cause not understood, as the additions are made on the different faces, a small space is left at the angles, and soon the form B is produced. If the process is continued, after a time the crystal is seen of the form C, and then of the form D, which is evidently an octahedron, with its angles truncated; and if the process were continued, a perfect octahedron would at length be formed. The octahedron is therefore a secondary of the cube. In the same manner a substance whose primary form is an octahedron, may produce a cubic crystal.

All substances are limited in the number of their crystalline forms. Thus, calcareous spar crystalizes in rhombohedrons, fluor spar in cubes, and quartz in six-sided pyramids; and these forms are so far peculiar to those substances, that fluor spar never crystalizes in rhombohedrons or six-sided pyramids, nor calcareous spar or quartz in cubes. Crystalline form may, therefore, serve as a ground of distinction between different substances. But the composition of substances having the same form is not necessarily the same, nor are

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crystalizes, what is first formed? Explain the mode in which secondary forms result. May crystalline form serve as a means of distinguishing different substances?

the crystalline forms of the same substances always identical.

204. *Isomorphism*.—Isomorphous substances (from *isos*, equal, and *morphe*, form), are such as may be substituted one for another in compounds they form with other substances, without changing the form of the crystals. The several varieties of alum furnish a good example. Thus, common alum ( $\text{HO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{HO}$ ) usually crystallizes in octahedrons; but for the alumina (which is the sesquioxide of aluminum) the sesquioxide of chromium may be substituted, producing chrome alum ( $\text{KO}, \text{SO}_3 + \text{Cr}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{HO}$ ), or the sesquioxide of iron, producing iron alum ( $\text{KO}, \text{SO}_3 + \text{Fe}_2\text{O}_3, 3 \text{SO}_3 + 24 \text{HO}$ ), and the crystals have the same external form. These alums are also very similar in other properties. These several sesquioxides are therefore said to be isomorphous; and numerous similar groups might be formed, but a further discussion of the subject would be unsuited to this work.

205. *Dimorphism*.—A substance is sometimes found, when crystalizing at different times and under different circumstances, to form crystals which belong to two different primary forms, and is then said to be dimorphous. (Carbonate of lime and sulphur are of this kind.) The term is from *dis*, double, and *morphe*, form.

204. What are isomorphous substances?

205. When is a substance said to be dimorphous? What substances are mentioned as being dimorphous?

# PART III.

## INORGANIC CHEMISTRY.

### NON-METALLIC ELEMENTS.

206. The substances usually reckoned in this class are thirteen in number; viz.,—

|           |             |           |
|-----------|-------------|-----------|
| Oxygen,   | Phosphorus, | Chlorine, |
| Hydrogen, | Boron,      | Iodine,   |
| Nitrogen, | Silicon,    | Bromine,  |
| Carbon,   | Selenium,   | Fluorine. |
| Sulphur,  |             |           |

These have been variously classified by different writers, but nothing would be gained by it in so elementary a work as the present. We therefore proceed to discuss them in the order mentioned, discussing also, under each after the first, the more important compounds it forms with any of the preceding elements.

### OXYGEN.

*Symbol, O; Equivalent, 8; Density, 1.10*

207. *History.*—Oxygen (from *oxus*, acid, and *gennao*, to produce) was discovered by Priestley and Scheele, independently of each other, in 1774. It has been called *empyreal air*, because it supports combustion, and *vital air*, because necessary to respiration. It is probably the most abundant

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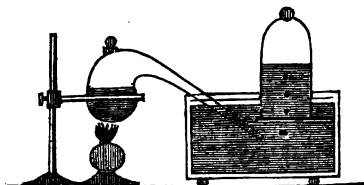
206. What are the thirteen non-metallic elements?

207. What is the derivation of the name oxygen? By whom was oxygen discovered? Why has it been called *empyreal air*? Why *vital air*? What is said of its abundance?

of the elementary substances, and constitutes a large part of the mass of the earth; it also forms an ingredient of nearly all animal and vegetable substances.

208. *Preparation.*—Oxygen is a gaseous substance, and may be obtained from several sources; but the best method to procure it, when only a small quantity is required, is to heat an ounce or less of chlorate of potash in a green glass flask or retort. This salt is composed of chloric acid,  $\text{ClO}_3$ , and potash,  $\text{KO}$ ; and, when heated nearly to redness, gives up the whole of its oxygen, as shown by the following formula. Thus,  $\text{KO,ClO}_3 = \text{KCl} + 6\text{O}$ ; each atom of the salt yielding one atom of chloride of potassium, and six atoms of oxygen. The process succeeds better if a little peroxide of manganese is mixed with the salt before heating it. One ounce of chlorate of potash, mixed with forty grains of peroxide of manganese, will yield a little more than two gallons of the pure gas.

209. The accompanying figure will serve to illustrate the arrangement of the apparatus required for the experiment. The salt, contained in a retort, is heated by a spirit-lamp, which produces no smoke, and the gas, as it forms, passes under a receiver filled with water, and placed on a shelf in a pneumatic cistern, a section of which is shown in the figure. The receiver is open at the



208. What is its state? What is the best mode of preparing it? What is chlorate of potash composed of? How many atoms of oxygen are yielded by each atom of the salt? What compound is formed at the same time? What other substance should be mixed with the salt before heating it? What quantity of oxygen may be obtained from an ounce of the salt?

209. Describe the apparatus for preparing the gas. Why is a spirit-lamp used, rather than one with oil? Why does the gas rise

bottom, and it is first filled with water by plunging it in the cistern, and then bringing it to its upright position, and raising it carefully to its place upon the shelf, which is just beneath the surface of the water. The water rises in the receiver, in consequence of the atmospheric pressure (see the author's *Natural Philosophy*, p. 115); and when the gas is forced underneath, it rises in bubbles, displacing the water, and occupying the highest part of the receiver, — the shelf being supposed to have an aperture in it, to allow the gas to pass upward, and the water also to escape.

When a large quantity of oxygen is to be obtained, it is more economical to make use of saltpetre (nitrate of potash); but a much greater heat is required to decompose it, and an iron retort must therefore be substituted, instead of glass. The iron retort containing the saltpetre is placed in a furnace, the heat of which can be easily regulated, and a lead tube is connected with it, leading to the pneumatic cistern. As soon as the bottle has attained a full red-heat, the gas begins to come over; and if care is taken to prevent the heat becoming too great, very pure oxygen will be obtained. The changes that take place are illustrated by the following formula:— $\text{KO}, \text{NO}_3 = \text{KO}, \text{NO}_2 + 2 \text{O}$ . Thus, each atom of nitrate of potash yields one atom of hyponitrite of potash, and two atoms of oxygen.

This gas may also be procured from the peroxides of manganese, lead, and mercury, and from other substances. Whatever mode of preparing it may be adopted, the first portions of gas that come over should always be allowed to escape, as it will be mixed with atmospheric air, contained in the apparatus at the beginning of the operation.

Oxygen gas is also given off by plants under the influence of light. Let a sprig of mint be placed in a white glass

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in the receiver through the water? Describe the mode of preparing oxygen from saltpetre. What other substances are mentioned

globe, which is then to be filled quite full of spring-water, and the mouth inverted in a tumbler of water, as shown in the figure. It is then to be placed in the direct rays of the sun; and in a short time, bubbles of gas will be seen collecting in the upper part of the glass, which is nearly pure oxygen.



210. *Properties.*—Pure oxygen is a colorless gas, without odor or taste, and has never yet been reduced to the liquid state by any degree of cold or pressure. It is very slightly absorbed by water, 100 cubic inches of that liquid taking up 3 or 4 of the gas. It is heavier than air, 100 cubic inches weighing 34.19 grains, while the same volume of air weighs only 31.01 grains. Its density is therefore 1.102. It has a very extensive range of affinity, entering into combination with all, or nearly all, the other elements.

Oxygen is a powerful supporter of combustion; and all substances that are capable of burning in the open air, burn in it with far greater brilliancy. A piece of wood, on which the least spark of light is visible, bursts into flame the moment it is put into a jar of oxygen; lighted charcoal emits beautiful scintillations; and phosphorus burns with so powerful and dazzling a light that the eye cannot bear its impression. Even iron and steel, which are not commonly ranked among the inflammables, undergo rapid combustion in oxygen gas.

The combustion of iron and steel is effected by introduc-

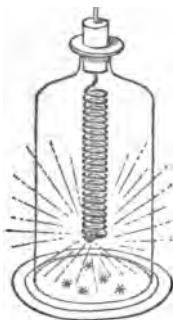
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from which oxygen may be prepared? Describe the mode of obtaining oxygen from plants.

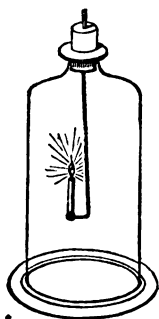
210. Mention some of the properties of this substance. Has it ever been reduced to the liquid state? Is it absorbed by water? What is its specific gravity, as compared with atmospheric air? What is said of its affinity for the other elements? What is said of its power of supporting combustion? How may a wire of iron



ing it in the form of wire or thin slips,—as pieces of watch-spring,—into a vessel of the gas, as shown in the figure. The combustion is commenced by attaching to the lower extremity a piece of spunk or other combustible, which is ignited the moment it is to be introduced into the gas. As the combustion progresses, if the cork is tight, the water contained around the bottom of the receiver in the shallow dish is seen to rise, and more must be poured in, to prevent the entrance of air from without.



This is occasioned by the absorption of the oxygen by the iron, to form oxide of iron, which falls in melted globules into the dish. When a lighted candle is let down by a wire into a jar of this gas, as in the figure, the case is different; the candle burns for a time with increased splendor, but soon the flame begins to diminish, and at length entirely disappears, without any diminution of the volume of gas contained within. If the candle be relighted and returned to the receiver, it is now instantly extinguished, the gas having lost entirely its power of supporting combustion. The reason is, that the oxygen has disappeared, and a new gas, carbonic acid ( $\text{CO}_2$ ), taken its place, which has exactly the same volume as the oxygen from which it was formed. If a piece of burning charcoal had been used, the result would have been the same.




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or steel be made to burn in it? Why does the water rise in the receiver as the combustion proceeds? Why does it not rise when a candle is burned in it? Why will not the candle burn if placed a second time in the gas?


211. *Ordinary combustion* consists in the union of combustible matter with oxygen, and is usually attended by the evolution of heat and light. A new substance is also formed, which may be solid, liquid, or gaseous. When iron is burned, a solid product (oxide of iron) results, which just equals the weight of the iron and oxygen together, that have disappeared during the operation. It is evident that in every case the product of the combustion must be equal in weight to that of the oxygen and other substance which have combined.

Combustion may, however, be produced without oxygen; a piece of phosphorus or powdered antimony, let down into a receiver filled with chlorine, will take fire spontaneously, and burn with the evolution of light and heat; so that ordinary combustion can only be considered as a particular case of chemical action.

Combustion is the great source of artificial heat and light (114). To produce an intense heat, means are contrived to force large quantities of air (one-fifth of which is oxygen) in contact with a mass of ignited coal, the carbonic acid formed being allowed to escape freely. To produce light, we burn oil, tallow, or other substances which contain a large proportion of the same material as coal, as we shall see hereafter. By supplying the burning body with pure oxygen, the intensity of both the heat and light is greatly increased. A very considerable heat is also produced, sim-

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211. What is ordinary combustion? When iron is burned in oxygen gas, what compound is produced? When a substance is burned, to what must the weight of the compound produced always be equal? May combustion take place without oxygen? What instances are mentioned? What may ordinary combustion then be considered? What is the great source of artificial heat? How is an intense heat produced? If the burning body were supplied with pure oxygen, what would be the effect?



ply by blowing with a proper blowpipe through the flame of a lamp or candle, which is sufficient for numerous small operations.

212. *Respiration* is also supported by oxygen gas, which is absolutely essential to the process; no animal can live in an atmosphere that does not contain it. A small animal, as a bird, confined in a close box, feels no inconvenience for a time; but the oxygen gradually is absorbed, carbonic acid gas taking its place, and respiration becomes laborious, until at length the animal dies for the want of oxygen. Pure oxygen, however, does not answer the purposes of respiration, as it excites the vital action too much, producing various inflammatory symptoms, and at length death, as the result of the over-action.

213. *Manipulation of Gases.*—The general method of collecting oxygen, described above, answers for all the gases that are not absorbed by water. In the same mode, also, a gas may be transferred from one receiver to another. When a gas is to be collected that is largely absorbed by water, some other liquid must be used, as mercury, or a saturated solution of salt; or the air may be removed by the air-pump, and then the gas admitted.

## HYDROGEN.

*Symbol, H; Equivalent, 1; Density, 0.069.*

214. *History.*—This gas was first described by Cavendish

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212. Is oxygen essential to the support of animals? What will be the effect of confining an animal in a close box? Will pure oxygen answer for the support of respiration?

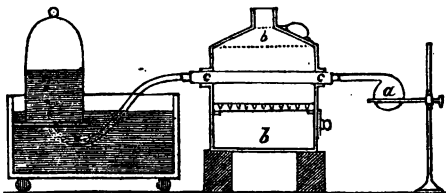
213. What is the method to be adopted in the manipulation of gases that are absorbed by water?

214. By whom was hydrogen first described? What was it

in 1766, and received from him the name of *inflammable air*, because of its combustibility. It has received its present name because it forms a part of water (from *hudo*, water, and *gennao*, to produce). It is not found free in nature, but constitutes one-ninth part of water, and enters into nearly all animal and vegetable substances.

215. *Preparation.*—Hydrogen gas is always procured by the decomposition of water, either directly or indirectly. The direct method consists in passing the vapor of water over metallic iron, heated to redness. This is done by putting iron wire into a gun-barrel open at both ends, to one of which is attached a retort containing pure water, and to the other a bent tube. The gun-barrel is placed in a furnace, and when it has acquired a full red-heat, the water in the retort is made to boil briskly. The gas, which is copiously disengaged as soon as the steam comes in contact with the glowing iron, passes along the bent tube, and may be collected in convenient vessels, by dipping the free extremity of the tube into the water of a pneumatic trough.

The arrangement of the apparatus will be seen by the accompanying figure. *a* is the retort contain-



ing the water, *bb*, furnace, with the gun-barrel, *cc*, in which are the iron turnings to be heated, and at the left is the receiver to collect the gas as it is formed.

The second, or indirect method, which is the one usually

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then called? Why did it receive its present name? Is it formed naturally in a free state? In what is it found?

215. From what is hydrogen always prepared? Describe the method of preparing it by the decomposition of water by means of iron. Describe the second and more common mode. Describe

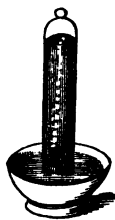
adopted in practice, consists simply in dropping pieces of zinc (or iron) into sulphuric acid, diluted with five or six times its weight of water, and contained in a convenient retort. Action immediately commences, without the aid of



heat, and the gas may be collected over water. A jar prepared as in the figure is very convenient for the purpose. The water and zinc are first introduced, and after the cork with the tubes is carefully inserted in its place, the acid is poured in through the long-necked funnel. The gas is collected by means of a tube leading from the cover to a

receiver, as before.

Hydrogen gas is also very readily procured by the action of metallic potassium or sodium upon water. A small re-



ceiver is first filled with water, and then a piece of the metal, wrapped in bibulous paper, is quickly placed under it; as soon as the paper becomes moistened, violent action takes place, and the hydrogen that is liberated rises to the upper part of the receiver. This method, on account of the high price of potassium and sodium, is very expensive.

**216. Properties.**—Pure hydrogen gas is without color, odor, or taste, and refracts light powerfully. It has never yet been reduced to the liquid state. It does not support respiration, but may be breathed, when mixed with air, without injury.

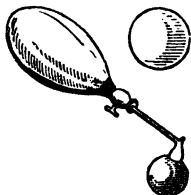
It is the lightest substance known, and is therefore often

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the mode of preparing it by means of metallic potassium or sodium.

**216. Describe some of the properties of hydrogen. What is said**

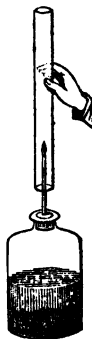
used for filling balloons. It is sixteen times lighter than oxygen, and more than fourteen times lighter than atmospheric air, 100 cubic inches weighing only 2.14 grains. Soap-bubbles filled with it rise readily through the air. They may be formed very easily by attaching a common tobacco-pipe by its stem to a gas-bottle filled with the gas, and forcing out the gas slowly, immediately after dipping the mouth of the pipe in a strong solution of soap in warm water.



Hydrogen gas is eminently combustible, and burns with a feeble yellowish flame. This may be shown by pouring some dilute sulphuric acid upon some pieces of zinc in a vial, and inserting a cork with a small glass tube or pipe-stem, as shown in the accompanying figure. In a short time a jet of hydrogen will issue from the tube, and may be inflamed. This is often described as the *philosophical candle*.



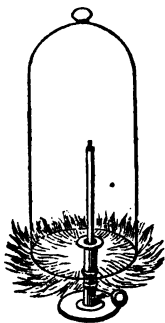
If, now, as the jet continues to burn, a glass tube, not more than half an inch in diameter, and one or two feet long, be held over it, and properly managed, a clear musical note will be produced, its pitch depending upon the length and diameter of the tube. It is occasioned by successive explosions within the tube, which follow each other so rapidly as to cause the air in the tube to vibrate, as in a musical instrument.



The following is an interesting and instructive experiment with this gas. Let a bell-glass receiver be filled with it in the pneumatic cistern, and then,

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of its lightness? What use is often made of it? How may soap-bubbles be formed with it? How may its combustion be shown? How may musical sounds be produced by it? When a receiver



carefully lifting it with the left hand, with the right hand pass up into the interior a lighted candle, as represented in the figure. As the flame enters the hydrogen, it will take fire with a slight explosion, and continue to burn where it is in contact with the air; but the candle being carried farther upward into the pure hydrogen, will be extinguished. The hydrogen, being combustible, is inflamed by the burning candle, but, not being a supporter of combustion, the candle is extinguished as soon as it is surrounded by it. The gas is retained in the receiver when lifted from its place, because of its being so much lighter than air.

Though hydrogen is the most volatile substance known, and universally classed with the non-metallic elements, by many it is believed to be really a metal, which class of bodies it resembles in some of its properties.

### *Compounds of Hydrogen and Oxygen.*

There are only two compounds of these substances known, the protoxide, or water, and the peroxide; and the latter is altogether an artificial product, of difficult formation.

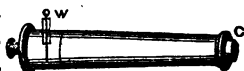
217. *Protoxide of Hydrogen, or Water*—HO, or Aq.; eq.,  $(1 + 8 =) 9$ .—This compound, considered in all its important

filled with it is lifted from its place, why does not the gas instantly escape? If a lighted candle is raised into the gas, what will be the effect? Is it a supporter of combustion? Why does the gas burn only at the surface, when it comes in contact with the air? What class of bodies does hydrogen, in many of its properties, resemble? How many compounds of oxygen and hydrogen are there?

217. What is the common name for protoxide of hydrogen?

relations, and absolutely universal diffusion, is probably the most important substance known to man. It is the sole product of the combustion of hydrogen, whether in the open air or mixed with oxygen gas. In the experiment for producing musical sounds, the water that is formed will be seen to condense in considerable quantity on the inside of the glass tube, at the beginning of the process, but it will be evaporated when the tube becomes hot.

The affinity of hydrogen for oxygen is very great, but the two gases do not combine spontaneously, even if kept together for any length of time. We have seen above (192) that two measures of hydrogen combine with exactly one measure of oxygen; and the mixture may be exploded by the approach of flame, by the electric spark, by intensely heated metal, or by the mere presence of spongy platinum, a substance that will be described hereafter. To explode the mixed gases by the electric spark, the spark must be made to pass through them. This is accomplished in the following manner. A small metallic vessel, as a miniature cannon, has a metallic wire, W, inserted in one side through a piece of wood or ivory, so as to extend nearly through to the other



side, as shown in the figure. The piece is then to be filled with the proper mixture of the gases, and a cork, C, inserted in the muzzle. If, now, a spark of electricity be communicated to the ball of the wire W, in escaping from the other end it ignites the gases, and the cork is forced out with a loud report. If a mixture of equal parts of hydrogen and atmospheric air is used, the effect will be nearly the same.

The ignition of hydrogen by spongy platinum is well

What is said of its importance to man? What is formed when hydrogen is burned? How is this shown in the experiment for producing musical sounds? Will oxygen and hydrogen combine spontaneously? In what proportion by measure do they unite? How may the mixture be exploded? By what means is the elec-



shown by holding a small piece of this substance in a jet of the gas, by means of a small wire twisted round it. The platinum must be perfectly dry. It gradually becomes heated to redness, and soon the jet is inflamed. The common *hydrogen fire-apparatus* acts upon this principle. Its construction is shown in the figure in the margin. A



A cylindrical glass vessel, A, is partly filled with dilute sulphuric acid, and in it is a small glass receiver, B, firmly cemented at the top into a cap connected with the brass cover. By the action of the acid upon a piece of zinc, Z, suspended inside of this receiver near the bottom, it is soon filled with hydrogen gas, which, on turning the faucet F, is forced out by the rise of the liquid upon a piece of platinum sponge, contained in the cup C. Soon the platinum is heated so as to inflame the jet of hydrogen, from which a candle can be at once lighted. The platinum sponge often loses its property of inflaming hydrogen, but recovers it again by being heated.

*The compound blowpipe*, which is an invention of Dr. Hare of Philadelphia, is a contrivance by which two jets, one of hydrogen and another of oxygen, are made to issue together, and are inflamed as they escape. The gases are brought by flexible tubes from separate gas-holders, so as to discharge, as near as may be, two measures of hydrogen to one of oxygen. The heat produced by this instrument is very great, probably exceeding that produced by any other means. Platinum and other substances incapable of fusion in the hottest furnaces, are melted, and often even volatilized by it. A small piece of lime, held in the flame, becomes intensely heated, and glows with a brilliant light, exceeding

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tric spark passed through the mixture? Describe the hydrogen fire-apparatus. The compound blowpipe. The Drummond light.

any other that can be produced artificially. It is known under the name of the *Drummond light*, and is much used for practical purposes.

218. *Water*, at ordinary temperatures, is a transparent, colorless liquid, without taste or smell. In the open air, it boils at a temperature of  $212^{\circ}$ , and freezes at  $32^{\circ}$ . The vapor produced by boiling, familiarly called steam, is perfectly colorless and transparent, and has a density of 0.620, air being 1; 100 cubic inches weighing 14.96 grs. In the form of ice, its density is 0.92. A cubic inch of pure water weighs 252.458 grs., being 814 times as much as an equal volume of air would weigh. A cubic foot weighs about 1000 oz., or  $62\frac{1}{2}$  lbs. avoirdupois. Water is probably the most powerful solvent known. It is capable of combining, in definite proportions, with many substances, forming compounds which yet remain perfectly dry. They are usually called *hydrates*. Substances from which all water has been separated are said to be *anhydrous*.

Water is never found naturally perfectly pure; that of wells, springs, and rivers always contains carbonic acid and saline matter in solution, obtained while percolating through the soil; and that from rain or snow is impregnated with air and oxygen, and sometimes with other gases. It is obtained pure only by distillation; and even then, by standing for a time, it takes up more or less atmospheric air, which, however, does not unfit it for the ordinary operations of the laboratory in which it is required.

The different processes for procuring hydrogen, given

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218. What is water at ordinary temperatures? What are its boiling and freezing points? What is the density of steam, as compared with air? What is the density of ice, water being 1? What is the weight of a cubic foot of water? What is said of its solvent power? What are its compounds called? When is a substance said to be anhydrous? Is the water of wells and springs pure? How only may perfectly pure water be obtained? Explain

above, require some further explanation, before we dismiss the subject. The first method is founded on the fact that iron, at high temperatures, decomposes water when presented to it in the form of steam, the oxygen combining with the iron to form protoxide of iron, and the hydrogen being set free. The changes are thus represented:  $\text{HO} + \text{Fe} = \text{FeO} + \text{H}$ . The changes which take place in the second and more common process for procuring this gas, are more complicated. They are represented in the following formula: thus,  $\text{HO}, \text{SO}_3 + \text{Zn} = \text{ZnO}, \text{SO}_3 + \text{H}$ . In this case it will still be seen that it is the water which supplies the hydrogen. The oxygen of the water is transferred to the zinc, forming protoxide of zinc, with which the sulphuric acid immediately combines. When a piece of clean zinc is immersed in water, little action takes place, because the outside becomes coated with a thin film of oxide of zinc, which is insoluble in water; but if sulphuric acid is present, this oxide is instantly dissolved, and thus a clean surface constantly exposed to the water.

In the third process, the metal itself at once decomposes a portion of the water, forming a soluble oxide of the metal, and liberating the hydrogen. Thus,  $\text{HO} + \text{K} = \text{KO} + \text{H}$ .

219. *Peroxide of Hydrogen*— $\text{HO}_2$ ; eq.,  $(1 + 16 = )17$ .—This substance is formed only by a difficult and rather complicated process, and is easily decomposed into water and oxygen. It is a liquid, and has a specific gravity of 1.45, water being 1.

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the method of procuring hydrogen by the action of heated iron upon steam. Explain the second mode, by the use of sulphuric acid and zinc. Explain the last process described, by the use of metallic potassium or sodium.

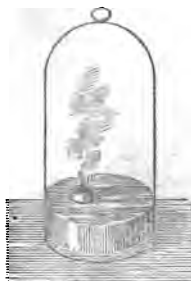
219. What is the composition of peroxide of hydrogen?

## NITROGEN.

*Symbol, N; Equivalent, 14.1; Density, 0.972.*

**220. History.**—The existence of this element has been known since 1772; and it was recognised as a constituent of the atmosphere in 1775. It was first called *azote* (from *a*, privitive, and *zoe*, life), because it does not support life; it receives its present name from the circumstance that it forms an ingredient of nitre.

**221. Preparation.**—Nitrogen gas is readily prepared, nearly pure, by burning a piece of phosphorus in a receiver over water. A small cup, C, containing a piece of phosphorus, is placed upon the surface of the water in the pneumatic cistern, the phosphorus ignited, and the receiver then placed over it. The phosphorus continues to burn, absorbing all the oxygen, and the water rises to supply its place, as shown in the figure. Some vapor of phosphorus, carbonic acid, and perhaps a trace of other gases, may be contained in the nitrogen thus prepared, but it will be found sufficiently pure for nearly all purposes. Other processes might be described for procuring it, but the above is the most speedy and convenient.



**222. Properties.**—Pure nitrogen is a colorless gas, wholly devoid of smell and taste, and is distinguished from other gases more by negative characters than by any striking qua-

220. Why has nitrogen been called *azote*? Why has it received its present name?

221. How may nitrogen gas be prepared? Why does the water rise in the receiver as the combustion goes on? Will the nitrogen thus prepared be pure?

222. What are some of the properties of nitrogen? Does it sup-

lity. It is not a supporter of combustion, but, on the contrary, extinguishes all burning bodies that are immersed in it. No animal can live in it; but yet it exerts no injurious action either on the lungs or on the system at large, the privation of oxygen gas being the sole cause of death. It is not inflammable, like hydrogen; though, under favorable circumstances, it may be made to unite with oxygen. It is slightly dissolved by water, and is sometimes found in the water of mineral springs, as at Lebanon, in the state of New York. 100 cubic inches of the gas weigh 30.16 grs., giving a specific gravity of 0.97.

### *Atmospheric Air.*

223. The earth is everywhere surrounded by a mass of gaseous matter, called the *atmosphere*, which is preserved at its surface by the force of gravity, and revolves with it around the sun. It is colorless and invisible, excites neither taste nor smell when pure, and is not sensible to the touch, unless when it is in motion. It possesses the physical properties of elastic fluids in a high degree. Its specific gravity is unity (1), being the standard with which the density of all gaseous substances is compared. It is 814 times lighter than water, and nearly 11,065 times lighter than mercury, 100 cubic inches weighing 31.01 grs.

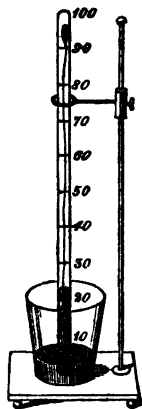
Atmospheric air is composed of nitrogen and oxygen, with a variable proportion of carbonic acid and watery vapor, and usually a trace of ammonia. Besides these, there may occasionally be other substances present, depending upon local causes, as the odoriferous principle of plants, and the

port combustion or respiration? Is it absorbed by water? Is it sometimes found in the water of springs?

223. What is meant by the atmosphere? Is the atmosphere visible? How many times is atmospheric air lighter than water? What is the weight of 100 cubic inches? What is the atmosphere

miasmata of marshes, which is supposed to be the chief cause of disease in many unhealthy situations; but they cannot be detected by chemical tests.

Instruments for determining the relative proportion of the gases composing the atmosphere are called *eudiometers*. The following contrivance answers the purpose very well. Let a glass tube, closed at one end, and graduated to 100 parts, with a small piece of phosphorus supported in it on a wire near the top, be placed as in the figure, with the open end immersed in a vessel of water. The phosphorus gradually absorbs the oxygen of the air in the tube, and the water rises to supply its place. In one or two days, depending upon the temperature, the absorption will be complete; and the number of the division of the tube now filled with water will indicate the proportion of oxygen.



By the above and other similar modes of analysis, it is found that the atmosphere in 100 parts is composed of—

|                | <i>By Weight.</i> | <i>By Measure.</i> |
|----------------|-------------------|--------------------|
| Nitrogen ..... | 76.9              | 79.3               |
| Oxygen .....   | 23.1              | 20.7               |
|                | <hr/> 100         | <hr/> 100          |

The proportion of carbonic acid varies from 2 to 6 parts in 10,000 of air.

The atmosphere is believed to extend to the height of about forty-five miles, becoming continually less and less dense from the surface upward; and presses by its gravity

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composed of? What are instruments for determining the relative proportions of the gases composing the atmosphere called? Describe the eudiometer figured in the margin. What are the proportions of nitrogen and oxygen by weight and by volume? What is the proportion of carbonic acid usually present? How high does

upon the surface with a force equal, ordinarily, to about 15 lbs. to the square inch. It is capable of supporting a column of water about 34 feet, and a column of mercury about 30 inches in perpendicular height.

The chief chemical properties of the atmosphere are owing to the presence of oxygen gas. Air from which this principle has been withdrawn, is nearly inert. It can no longer support respiration and combustion, and metals are not oxidized by being heated in it. The uses of the nitrogen are in a great measure unknown. It has been supposed to act as a mere diluent to the oxygen; but it most probably serves some useful purpose in the economy of animals and plants, the exact nature of which has not been discovered.

The question has often been discussed, whether the oxygen and nitrogen of the atmosphere are to be considered as chemically combined, or only in a state of mixture; but the latter opinion now generally prevails. It has been supposed



that if they are merely in a state of mixture, oxygen, being the most dense, ought to settle towards the surface of the earth; but it is found by experiment that gases, whatever may be their relative density, when brought in contact, mix uniformly with each other. Thus, if two bottles, *a* and *e*, are each filled with a gas, the most dense being in the lower, and are then made to communicate together by means of the faucets *b* and *c*, and connecting tube *d*, the two gases will gradually diffuse themselves equally through the whole space. The mixture of the gases will even take place through thin membranes, whether animal or vegetable; the least dense of the gases passing much the most rapidly.

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the atmosphere extend? What is the amount of atmospheric pressure upon each square inch of surface? To what are the chief chemical properties of the air owing? Are the gases in the atmosphere to be considered in combination, or only in mixture? Why

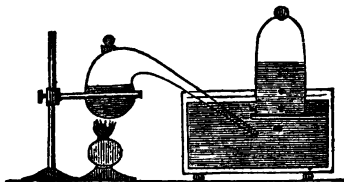
There is still one circumstance for consideration respecting the atmosphere. Since oxygen is necessary to combustion, to the respiration of animals, and to various other natural operations, by all of which that gas is withdrawn from the air, it is obvious that its quantity would gradually diminish, unless the tendency of these causes were counteracted by some compensating process. This, to some considerable extent, is accomplished by vegetation, as it is found that healthy plants, under the influence of the sun's light, are constantly absorbing carbonic acid from the air, the carbon of which is retained, while the oxygen is returned to the air, as we have before seen (216). Still, it has been calculated that the loss of oxygen employed in respiration, over the whole surface of the globe, in 100 years, would not exceed  $\frac{1}{7380}$  part of the whole quantity contained in the atmosphere.

### *Compounds of Nitrogen and Oxygen.*

224. Oxygen combines with nitrogen in five different proportions, forming the compounds  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{NO}_3$ ,  $\text{NO}_4$ , and  $\text{NO}_5$ ; the last three of which are acids.

225. *Protoxide of Nitrogen*— $\text{NO}$ ; eq.,  $(14.1 + 8 =) 22.1$

—This is a colorless gas, of a sweetish taste and smell, and is sometimes called *nitrous oxide*. 100 cubic inches of it weigh 47.22 grs., its density therefore being 1.52. It



is best prepared as shown in the figure, by heating nitrate

does not the heaviest settle to the surface? Under what circumstances do plants give out oxygen to the air?

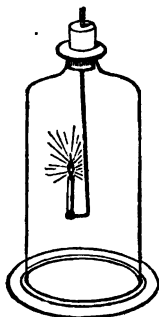
224. In how many proportions do oxygen and nitrogen combine? What is the relative proportion of oxygen in each?

225. What are some of the properties of protoxide of nitrogen?



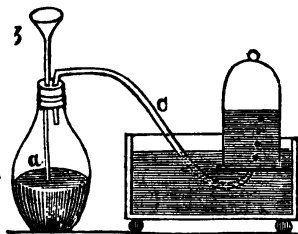
of ammonia, by means of a spirit-lamp, in a glass retort. The sole product of the operation, when carefully conducted, so as not to raise the temperature too high, are water and the gas in question. Thus, nitrate of ammonia,  $\text{NH}_4\text{NO}_3$ , when heated, becomes  $3\text{HO} + 2\text{NO}$ ; each atom of the salt yielding 3 atoms of water and 2 atoms of the gas.

This gas may be collected over water, but should not be



be allowed to stand long over it, as it is gradually absorbed. A lighted candle and phosphorus burn in it with great brilliancy, and sometimes the combustion of iron wire in it may be effected, but not without difficulty. By a pressure of about 50 atmospheres it is compressed into a liquid, which freezes or becomes solid at about  $150^\circ$  below zero; and by the evaporation of this solid, a temperature considerably lower than this has been attained. Its

action on the system, when breathed, is very remarkable, producing a species of intoxication, which has acquired for it the name of *laughing gas*. In a few cases, when it has been inspired, injurious effects have resulted; and it should never be breathed but with caution.



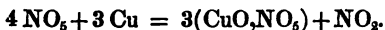
226. *Binocide of Nitrogen*— $\text{NO}_2$ ; eq.,  $(14.1 + 16 =) 30.1$ .—This is also a gaseous substance, and is easily obtained by pouring nitric acid upon pieces of copper contained in a glass retort. The arrangement shown in the figure is very

From what is it prepared? Explain the process. Will this gas support combustion? Why has it been called laughing gas?

226. How is binocide of nitrogen prepared? Explain the pro-

convenient for the purpose. Into the glass vessel *a* put some clean pieces of metallic copper, and then introduce the cover, through which passes the glass tube *b*, with a funnel at top, and extending nearly to the bottom of the vessel, and a lead tube, *c*, bent at right angles, to convey away the gas as it is formed. The cover must fit very accurately, in order to prevent the escape of the gas, which is rapidly formed as soon as a little nitric acid is introduced by the funnel and tube *b*. It may be collected over water, but a small proportion is absorbed.

The changes which take place between the copper and the acid are indicated as follows :—



Thus, from 4 atoms of nitric acid and 3 of copper, there are formed 3 atoms of nitrate of protoxide of copper, and one of the binoxide of nitrogen.

Binoxide of nitrogen, called also *nitric oxide*, is a colorless gas, of a density 1.04, 100 cubic inches weighing a little more than 32 grs. Its most striking property is its strong affinity for oxygen, although most substances introduced into it in a state of combustion are extinguished. Charcoal and phosphorus, however, burn in it with great splendor. When allowed to escape into the air, it forms, with the oxygen of the air, dense orange fumes of nitrous acid. Thus, if a bell-glass receiver, filled with it over water, be suddenly inverted in the air, the dense orange fumes of nitrous acid formed by its union with the oxygen of the atmosphere will



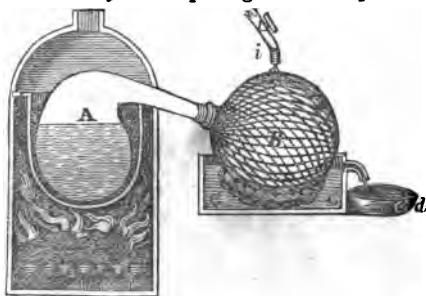
cess, and the chemical changes that take place. What are some of the properties of this substance? What is said to be its most striking property? What are produced when it is allowed to escape in the air?

rise for a few moments from its interior, like smoke from a chimney.

227. *Hyponitrous Acid*— $\text{NO}_3$ ; eq.,  $(14.1 + 24 =) 38.1$ .—This acid is formed by mixing 4 measures of binoxide of nitrogen with 1 of oxygen, both perfectly dry, and subjecting the mixture to a cold of zero. It is a colorless liquid, which is at once decomposed by water into nitric acid and the binoxide. It combines with sulphuric acid and water, and forms a solid compound.

228. *Nitrous Acid*— $\text{NO}_2$ ; eq.,  $(14.1 + 32 =) 46.1$ .—This substance is formed, as we have seen, whenever binoxide of nitrogen comes in contact with oxygen. It may also be prepared by other means. At  $32^\circ$  it is a yellow liquid, of a density of 1.45, and boils at  $82^\circ$ .

229. *Nitric Acid*— $\text{NO}_5$ ; eq.,  $(14.1 + 40 =) 54.1$ .—Nitric acid, or *aqua fortis*, is always seen as a liquid, and is best obtained by decomposing nitrate of potash or nitrate of soda



by strong sulphuric acid, by the aid of heat. The salt, previously well dried, is placed in a retort of hard glass, A, with an equal weight of strong sulphuric acid, in

a furnace, and surrounded at the bottom with sand. A moderate heat is applied, and the nitric acid, as it is separated, distils over into the receiver B, where it is condensed. To

227. What is the composition of hyponitrous acid? With what does it form a solid compound?

228. What is the composition of nitrous acid?

229. What is the common name for nitric acid? How is it obtained? Describe the mode of manufacturing it. What are some

render the condensation more complete, the receiver may be surrounded with a net-work, and cold water from a pipe, i, made to fall constantly upon it. The water escapes by the troughs CC and *ed*.

Nitric acid, as thus formed, is a dense liquid, of a yellow or orange color, and always contains more or less nitrous acid mixed with it. In its most condensed state it has a density of 1.52, and boils at  $248^{\circ}$ . It always contains a portion of water, it being impossible to obtain the free acid. It is one of the most powerful acids known, and oxydizes many substances powerfully. Powdered charcoal and oil of turpentine are ignited by it, and most animal and vegetable bodies disorganized. A small drop on the skin will, in a few seconds, destroy its vitality, and produce a permanent yellow spot. There are two varieties of it in commerce, called *single* and *double aquafortis*, the latter of which is much the strongest, but its specific gravity seldom exceeds 1.40.

Nitric acid is much used in the arts for etching on copper, as a solvent for the metals, &c., and as a tonic in medicine. In the laboratory of the chemist, it is in constant and most important use in a great variety of operations.

### *Compounds of Nitrogen and Hydrogen.*

230. *Ammonia*— $\text{NH}_3$ ; eq.,  $(14.1 + 3 =) 17.1$ .—This gaseous substance is the only compound of nitrogen and hydrogen that is known. It has been called by a variety of names, as *hartshorn*, *spirits of hartshorn*, *volatile alkali*, &c. It has

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of its properties? What is its density when most concentrated? Can it be freed from water? How is powdered charcoal affected by it when warm?

230. What is ammonia composed of? What are some of the names by which it is called? In what has it sometimes been detected? How may it be readily obtained? What are some of its

sometimes been detected in rain-water, either alone or in combination with nitric acid; but it is readily obtained by heating the common solution of ammonia, called *aqua ammonia*, or a mixture of sal ammonia and recently slaked lime. It is a colorless gas, and possesses a very pungent odor, by which it may always be distinguished. By a pressure of six or seven atmospheres it is compressed into a liquid; it also takes the liquid form by the application of intense cold, under the ordinary atmospheric pressure. A lighted candle plunged into it is extinguished, but a small jet of it burns in oxygen gas. Its density is about 0.59, 100 cubic inches weighing 18.29 grs.

This gas is largely absorbed by water, and must therefore always be collected over mercury. Water at  $32^{\circ}$  is capable of dissolving 780 times its own volume of it, and then forms the *liquid ammonia*, or *aqua ammonia* of commerce. As the gas is absorbed, the water increases considerably in volume, so that, when saturated, its density is only 0.87, and it contains 32 per cent. of the gas.

Ammonia is used extensively in the laboratory of the chemist, and in medicine. Solution of ammonia, taken internally in considerable quantity, has been known to produce death; and the gas, if inspired too long, is apt to occasion inflammation in the throat and lungs.

231. *Ammonium*— $\text{NH}_4$ , or Am; eq.,  $(14.1 + 4 =) 18.1$ .—This supposed substance has never been obtained in a separate state, but there are many reasons to believe that it enters into the composition of several compounds. When a solution of sal ammoniac, containing a globule of mercury, in contact with the negative electrode of a galvanic battery, is decomposed by the current, the mercury swells up very

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properties? May it be compressed into the liquid form? Will it support combustion? What is said of its absorption by water?

231. What is ammonium? How may an amalgam of this supposed substance be prepared? Can this amalgam be preserved?

much, and becomes less fluid, but retains its metallic lustre, and in every respect resembles an *amalgam*. The same substance is also formed when an alloy of mercury and potassium is immersed in a strong solution of sal ammoniac, without the aid of the electric current.

This compound, when removed from the solution in which it was formed, rapidly undergoes spontaneous decomposition, yielding ammonia and hydrogen; and the mercury is left unchanged. Now it is believed that the mercury is in combination with the compound in question ( $\text{NH}_4$ ), which therefore seems to perform the part of a metal, and has received the name *ammonium*. We shall have occasion to speak of it again, when we are prepared to introduce its compounds.

## CARBON.

*Symbol, C; Equivalent, 6.12; Density (crystalized), 3.52.*

232. *History.*—Carbon, though rarely met with in nature perfectly pure and uncombined, is one of the most important of the elements, forming, as it does, an essential ingredient of nearly all vegetable and animal bodies. It is found in a variety of forms, as *charcoal*, *mineral coal*, *graphite* or *plumbago*, and the *diamond*.

233. *Preparation.*—Carbon in the form of charcoal is prepared by heating wood and other substances, as gum, sugar, starch, ivory, and leather, in close vessels, by which means all the volatile substances contained in them are expelled, and the black carbon, mixed with more or less impurities, remains. Common charcoal is usually prepared by covering a quantity of wood with earth, so as to admit but

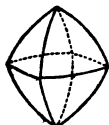
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232. Is carbon often met with in nature in a state of purity? What is said of its importance? In what different forms is it seen?

233. How is charcoal prepared? How is coke prepared? What

a small supply of air, and igniting it, by which means a part is consumed in charring the remainder. When the action is complete, the supply of air is stopped, and the fire extinguished. *Coke* is formed by subjecting bituminous coal to a similar process. From ivory, and other animal substances, *ivory-black* and *animal charcoal* are formed. *Lamp-black* is produced by burning rosin and other similar substances in close chambers, with only a limited supply of air.

234. *The diamond* is pure crystalized carbon, and is the hardest substance known in nature. The crystals are of the



form of the regular octahedron, but the faces are frequently a little convex, as shown in the figure. Such crystals, properly set, are used for cutting glass, a purpose for which they are admirably adapted. Heated intensely in the flame of the compound blowpipe, the diamond is entirely consumed, forming carbonic acid, just as if the same weight of pure charcoal had been consumed. Diamonds are generally very small, the largest ever found weighing less than six ounces. A single diamond has been sold for more than half a million of dollars. It is generally found in the same situations as gold and platinum. A few crystals of little value have been discovered in the vicinity of the gold mines in some of the southern states. It is a powerful refractor of light.

235. *Properties.*—The most important properties of crystalized carbon have been described above. In the form of charcoal it is a black, hard, brittle substance, perfectly insoluble in every liquid, but attacked and oxidized (229) by

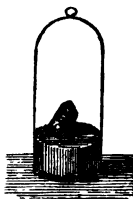
is ivory-black? What is animal charcoal? What is lamp-black?

234. What is the diamond? What is said of its hardness? What is the usual form of the crystals? What use is made of the diamond in the arts? What is the effect when the diamond is heated intensely? In what situations is the diamond usually found? What is said of its power of refracting light?

235. What are some of the properties of carbon? Can it be

strong nitric acid. It is a good conductor of electricity, but a non-conductor of heat; is little acted upon by air and moisture, and is perfectly infusible in the most intense heat that can be applied to it. Heated in the open air, it takes fire and burns freely, especially if in large masses, leaving a small residue of *ashes*, consisting of a mixture of earthy and alkaline salts.

Charcoal possesses the property of absorbing a large quantity of air, or other gases, at common temperatures, and of yielding the greater part of them again when it is heated. Different gases are absorbed by it in different proportions; thus, while charcoal from boxwood absorbs, in the space of forty-eight hours, 90 times its own volume of ammoniacal gas, 85 of hydrochloric, and 35 of carbonic acid, and olefiant gas, it will, in the same time, take up only 7.5 times its volume of nitrogen, and 1.75 of hydrogen. Recently-burned charcoal absorbs air and moisture so rapidly, for a few days, as materially to increase its weight. Both air and moisture are absorbed and retained with such force, that a red heat is required to expel them. This absorption of air may be readily shown in the following manner:—Let a piece of charcoal, of moderate size, be heated to redness for a few minutes, and then quenched under mercury, and placed under a receiver, over the mercurial cistern. The mercury will, in a few moments, begin to rise, in consequence of the absorption of the air within; and the process will continue for several hours.



Charcoal, likewise, absorbs the odoriferous and coloring principles of most animal and vegetable substances. When colored infusions of this kind are digested with a due

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fused? What takes place when it is heated in the open air? What is said of its power of absorbing gases? How may the ab-



quantity of charcoal, a solution is obtained which is nearly, if not quite, colorless. Tainted flesh may be deprived of its odor by this means, and foul water be purified by filtration through charcoal. The substance commonly employed to decolorize fluids is animal charcoal reduced to a fine powder. It loses the property of absorbing coloring matters by use, but recovers it by being heated to redness.

At very high temperatures charcoal has a higher affinity for oxygen than any other substance, and is therefore often heated with oxides of the metals to deoxidize them, or deprive them of their oxygen.

236. *Mineral coal* is of two kinds; the bituminous and the non-bituminous, or anthracite.

*Bituminous coal* is distinguished by its softening, like wax, when heated, and giving off much gas, which, of course, burns with flame. It is also much lighter than anthracite, and more easily ignited. Some of the different varieties of bituminous coal are *caking*, *splint*, *cherry*, and *cannel* coal. *Jet*, also, which is used in jewelry, is a bituminous coal; and in the same family may be included *wood* or *Bovey* coal, sometimes called *lignite*.

*Anthracite*, or *stone-coal*, differs from the above varieties in containing no bituminous matter; and, therefore, it yields no inflammable gas by heat. Its sole combustible ingredient is carbon; and, consequently, it burns without flame. It is found in different countries, but nowhere in such profuse abundance as in the eastern part of the State of Pennsylvania, which supplies most of the northern and eastern parts of the United States with fuel.

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sorption of air be shown? How is it used to decolorize liquids? What is said of its affinity for oxygen at high temperatures?

236. What two kinds of mineral coal are there? How do they differ from each other? What are some of the varieties of bituminous coal that are mentioned? How does anthracite or stone-coal differ from the above? Where is this variety of coal found in this

All the varieties of mineral coal are believed to have been formed from vegetable substances, which, in the changes the earth's surface has undergone, have become buried beneath it.

237. *Graphite*, or *plumbago*; called, also, very improperly, *black lead*, is carbon in a mineralized state, containing usually about 5 per cent. of iron. It is often found crystalized in thin scales.

Carbon is used as fuel; in forming gunpowder; as a pigment; in the formation of steel; as a polishing-powder; and in medicine, as an antiseptic, &c. &c. Graphite is used in the manufacture of drawing-pencils; and, also, in the manufacture of crucibles, or melting-pots, which are capable of withstanding great heat.

#### *Compounds of Carbon and Oxygen.*

238. Carbon combines with oxygen in two proportions, forming carbonic oxide (CO) and carbonic acid (CO<sub>2</sub>).

239. *Carbonic Oxide, Protoxide of Carbon*.—CO; eq. (6.1 + 8 =) 14.1. This is a gaseous substance, and is best prepared by heating a mixture of equal parts of dry, powdered chalk and iron-filings in a gun-barrel. The chalk, which is carbonate of lime, when heated, gives off its carbonic acid (the compound next to be described) in contact with the heated iron, by which one-half of its oxygen is instantly absorbed (215), and the carbonic oxide thus produced passes on, and may be collected over water. Thus,  $\text{CaO}, \text{CO}_2 + \text{Fe} = \text{CaO} + \text{FeO} + \text{CO}$ .

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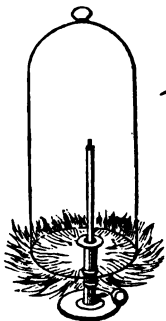
country? From what have all the different varieties of mineral coal been formed?

237. What is graphite or plumbago? What uses are made of carbon?

238. How many compounds of carbon and oxygen are there?

239. How is carbonic oxide prepared? Explain the process. What are some of its properties?

The density of the gas is about 0.97; 100 cubic inches weighing 30.20 grs. It is highly combustible, and burns with a beautiful, blue flame. It will not support respiration or combustion; and a lighted candle being immersed in it, as heretofore described in connection with hydrogen (216), is instantly extinguished.



240. *Carbonic Acid*.— $\text{CO}_2$ ; eq.  $(6.1 + 16 =)$  22.1.—Carbonic acid is remarkable as being the first gaseous substance recognized, after atmospheric air, which must always have been known. It was first described by Dr. Black, in 1757, and called, by him, *fixed air*, because he found it *fixed* in common limestone and magnesia; from which it may be expelled by heat, or by the action of hydrochloric, sulphuric, or any strong acid. It may be collected over



water, but a portion will be absorbed. A gas-bottle, of the form shown in the figure, is convenient for preparing it. Some fragments of marble, and water, are placed in the bottle, and the cover put on, and then strong hydrochloric acid is poured into the long-necked funnel. No heat is required.

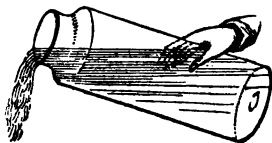
As thus prepared, carbonic acid is a colorless, inodorous gas, of specific gravity 1.52; 100 cubic inches weighing 47.14 grains.

It is so much heavier than atmospheric air, that it may be poured from one vessel to another without difficulty.

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240. For what is carbonic acid remarkable? Why has it been called fixed air? How may it be prepared from marble and hydrochloric acid? What are some of its properties? How may the

Let a bottle, with a wide mouth, be filled with the gas, and then plunge into it a piece of lighted paper, or other substance, so that some smoke may be mixed with it and render its motions visible. Then hold the bottle in the hand, as if pouring a liquid from it (as represented in the figure), and the motion of the gas, as it is emptied from it, will be made apparent to the eye.



By a pressure of thirty-six atmospheres, at  $32^{\circ}$ , it is converted into a beautiful transparent liquid, which may be frozen by intense cold, in the manner already explained (104).

It is capable of supporting neither combustion nor respiration;—a burning candle plunged into it is instantly extinguished; and a living animal, thrown into a vessel containing it, even though considerably diluted with air, soon dies. Carbonic acid is always produced by ordinary combustion; and lives have often been lost by persons placing an open dish of burning charcoal in their bed-rooms before retiring to rest. The oxygen of the air in the room is taken up by the carbon, and the gas in question takes its place, producing the effects described. It is produced, also, by the decay of animal and vegetable substances, and sometimes is found collected in caves and wells, and is called *choke-damp*. A person should never descend into a deep well without first testing the air contained in it by letting down a burning candle, which will usually be extinguished if this gas is present in sufficient quantity to be dangerous.

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pouring of it from one vessel to another be shown? What will be the effect of plunging a lighted candle into it? Will it support respiration? Why is it dangerous to have an open dish of burning charcoal in a close apartment? Where is this gas sometimes found collected?

241. *Soda-fountains* are formed by compressing a large quantity of this gas in water, contained in a strong vessel adapted to the purpose. When the tube leading from the fountain is opened, the water is forced out by the pressure, and effervesces violently by the escape of the gas. Soda-powders, &c., often used to produce an agreeable drink, in the absence of a soda-fountain, consist of bicarbonate of soda and tartaric acid, which, when mingled together in solution, produce, by chemical action, tartrate of soda, the carbonic acid passing off into the air with effervescence. So, also, the effervescence which takes place on opening a bottle of beer, cider, or champagne wine, is owing to the escape of this gas, which has been produced by the fermentation of the liquid. All kinds of spring and well-water contain it in small quantity, and become insipid to the taste by boiling, in consequence of the gas having been expelled. It is also always present in the atmosphere, as before stated.

Lime-water is an excellent test for carbonic acid; and a vessel of it being allowed to stand a few hours, becomes coated with a pellicle of carbonate of lime, by absorbing this gas from the air. So lime-water becomes milky by blowing into it with a tube from the lungs, for the same reason. A portion of the lime is changed into carbonate of lime, which is insoluble, and gives the water its milkiness.

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241. What are soda-fountains? Why does the water effervesce after escaping from the fountain? What occasions the effervescence when a bottle of beer, cider, or champagne is opened? What test for carbonic acid is mentioned? How will lime-water be affected by standing in the open air?

*Compounds of Carbon and Hydrogen.*

242. Carbon and hydrogen combine in a number of different proportions, producing compounds, several of which are of special interest, because of their isomeric character; but we shall here describe only two, both of which are gaseous, viz., *light carburetted hydrogen* ( $\text{CH}_4$ ) and *olefiant gas* ( $\text{C}_2\text{H}_2$ ).

243. *Light Carburetted Hydrogen*— $\text{CH}_4$ ; eq.  $(6.1 + 2 =) 8.1$ .—This gas, called also *fire-damp*, *hydrocarburet*, and *dicarburet of hydrogen*, is formed by the slow decomposition of wood, and woody substances under water, especially in warm weather; and may be obtained by stirring the mud and other matters at the bottom of stagnant pools, and collecting the bubbles of gas in a receiver, as they rise. It sometimes accumulates in large quantities in coal-mines, where it is formed by the action of water upon the coal. By the miners, it is called *fire-damp*.

It is a colorless, transparent gas, 100 cubic inches of which weigh 17.37 grains, giving it a specific gravity of 0.56. A burning candle is extinguished by it, but it is, itself, highly combustible, and burns with a feeble, yellow flame. Mixed with twice its own volume of oxygen, or seven or eight times its volume of air, it explodes violently by the electric spark, or on the approach of flame.

244. *Olefiant Gas*, or *Heavy Carburetted Hydrogen*— $\text{C}_2\text{H}_2$ ; eq.  $(12.2 + 2 =) 14.2$ .—This gas was first described in 1796, by some Dutch chemists, who gave it the name,

242. What compounds of carbon and hydrogen only will be here described?

243. Where may light carburetted hydrogen be found, in the warm season? How may it be procured? How is it formed in coal mines? What is it called? What are some of its properties? With what does it form an explosive mixture?

*olefiant gas*, because of its forming with chlorine a peculiar oil-like liquid. It is colorless and tasteless, and but slightly absorbed by water; 100 cubic inches weigh 30.41 grains, so that its density is 0.98.

Olefiant gas is prepared by mixing, in a capacious retort, one part of alcohol with four of concentrated sulphuric acid, and heating the mixture, as soon as it is made, by means of a lamp or ignited charcoal. The acid soon acts upon the alcohol, effervescence ensues, and olefiant gas passes over, mixed with other substances, chiefly sulphurous acid, from which it may be purified by washing it with solution of lime or caustic potassa.

As might be expected, olefiant gas does not support combustion; but a jet of it burns in the air, or in oxygen gas, with a brilliant white light. Mixed with oxygen, or air, in proper proportions, it explodes violently, like the preceding compound.

It should perhaps be stated that, by some, the equivalent of this gas is considered to be double of that given above, or 28.4 ( $C_4H_4$ ). Its equivalent has not been fully determined.

*Illuminating Gas* is usually a mixture of olefiant and light carburetted hydrogen gases, and is formed by distilling, in large cast-iron retorts, rosin, tar, or other resinous or oily substances, or bituminous coal. Besides the gases mentioned, there are also formed other hydro-carbons, but in less quantity. Illuminating gas is used in immense quantities in large cities, for lighting the streets, and for fixed lights in stores and other buildings.

A gas, not unlike that prepared by the distillation of coal, is often found to issue, ready formed, from the earth, and

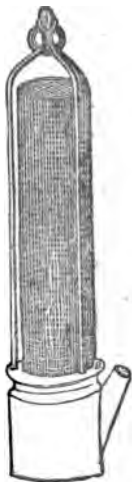
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244. Why has olefiant gas received this name? What are some of its properties? How is it prepared? What is illuminating gas? How is it formed? For what purpose is it used? Where is a gas

may be collected and used like that formed by art. The village of Fredonia, in the state of New York, is lighted by natural gas, in this way; and in some salt works in Virginia, it is said, no other fuel is used for boiling the brine.

245. *Safety-Lamp*.—The safety-lamp is the invention of Sir H. Davy, to avoid the danger of explosions from mixtures of the above gases with air, which often occur in coal-mines, when unprotected lamps are made use of. It consists simply of a common lamp, the flame of which is surrounded by wire gauze, as shown in the figure. But before proceeding to illustrate the mode in which it operates, some remarks on the general nature of flame will be necessary.

*Flame* is gaseous matter in a state of combustion, and is made incandescent by the intense heat of the combustion. Two gases are needed to produce it, one of which, in common language, must be combustible, and the other a supporter of combustion. The action is mutual between them;—neither will burn alone;—and a jet of either will burn in the other.



In the common lamp, or candle, the combustible gases are supplied from the oil, or tallow, which is gradually raised, by the capillary action of the wick, into the flame, where it is decomposed by the heat. As these gases, thus produced, escape from the wick, and come in contact with the oxygen of the atmosphere, they combine, producing the

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similar to this sometimes found? What village in the state of New York is lighted with such gas?

245. What is the design of the safety-lamp? Describe it. What is flame? Can a single gas burn alone? What two are needed for this purpose? Describe the mode in which the flame of a

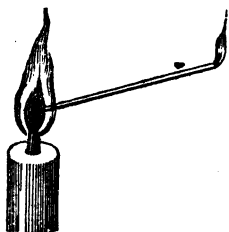


phenomena of light and heat, with which all are familiar. A careful inspection of the flame of a lamp or candle, as



it burns quietly, will show, that it is composed of three parts, viz :—1st, a central part, *a*, surrounding the wick, and extending a little above it, of gaseous matter that has emerged from the wick, and is making its way outward to the atmosphere, which it has not yet reached, and therefore has not yet become ignited; 2d, the bright part of the flame, *b, b*, which, in the form of a conical shell, incloses the part *a*, and consists of gaseous matter in a state of rapid combustion, the combustible particles, as they reach the air, uniting with its oxygen, with the evolution of much light and heat; and, 3d the part, *cc*, outside of the part last mentioned, composed chiefly of heated air, and mixed with a small portion of combustible matter in a state of ignition.

That the dark, interior portion, *a*, is composed of combustible gas, may be shown by inserting, in the centre of



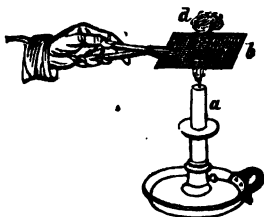
the flame, one end of a small glass tube, as shown in the figure, and conveying away a portion, and igniting it as it escapes at the other end. So, when the flame of a candle is suddenly extinguished, the heat in the wick continues, for a short time, sufficient to decompose the tallow, and the combustible gases

continue to rise in the form of smoke; and may often be again relighted by applying the flame of another candle to the ascending smoke, several inches above the wick.

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candle or lamp is produced? Of what three parts is it composed? How may it be shown that the dark interior consists of combusti-

Now, flame being only intensely-heated gaseous matter, it cannot pass through anything that will cool it down below the temperature at which the combustion of the gases takes place; and this effect, it is found, is produced by wire gauze. To show it, let a piece of such gauze, *b*, be held in the flame of a candle, *a*; the flame appears to be cut off by the gauze, and the gases pass through unconsumed, as shown at *d*, and, by dexterous management, may be relighted.



These principles being established, the mode in which the safety-lamp operates, to prevent an explosion of the mixed gases, is manifest. When the miner carries his lamp into an atmosphere charged with fire-damp, the flame begins to enlarge; and the mixture, if highly explosive, takes fire as soon as it has passed through the gauze, and burns on its inner surface, the whole inside appearing to be filled with flame. Whenever this takes place, the miner is obliged to retire, lest, by the intense heat, the wire of the gauze should be melted or oxydized, and the flame communicated to the mixed gases, without the lamp.

The operation of the lamp may be shown quite well, by pouring a little sulphuric ether into a common glass receiver, which should be inverted and agitated a little, so that it may be filled with a mixture of air and vapor of ether, and then letting the lighted lamp down into it. The mixture of air and vapor of ether entering through the gauze, burns brilliantly within the gauze, but the flame is not communicated to that without.

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ble gas? What will be the effect of holding a piece of wire gauze in the flame of a lamp? Explain the mode in which the gauze of the safety-lamp operates to prevent explosions of the mixed gases. Describe the experiment to show the operation of the lamp.

*Compounds of Carbon and Nitrogen.*

246. There are several compounds of these two substances, but we shall notice only one, the *bicarburet of nitrogen* ( $C_2N$ ), or *cyanogen* (from *kuanos*, blue, and *gennao*, to produce, because it is an ingredient of Prussian blue).

247. *Bicarburet of Nitrogen*, or *Cyanogen* —  $C_2N$ , or Cy; eq.  $(12.2 + 14.1 =) 26.3$ .—This is a gaseous substance, and is readily formed by heating bicyanide of mercury (to be hereafter described) in a glass retort by a spirit-lamp. It is colorless, has a very pungent odor, and is easily compressed into a liquid. Of the pure gas, 100 cubic inches weigh 56.47 grains, giving it a density of 1.82.

Cyanogen, though a compound, is remarkable for combining with the elementary bodies in the same manner as an element, forming a class of compounds which are called *cyanides*. Further remarks concerning it will be deferred to Organic Chemistry.

## SULPHUR.

*Symbol, S; Equivalent, 16.1; Density, 1.99.*

248. *History*.—Sulphur, called also *brimstone*, has been known from the remotest antiquity. It occurs, as a mineral production, in many parts of the world, particularly in volcanic regions, as in the neighborhood of Naples, and in the island of Sicily. In combination with several of the metals, as iron, lead, copper, &c., it is still more abundant, and is

246. Why has the bicarburet of nitrogen been called cyanogen?

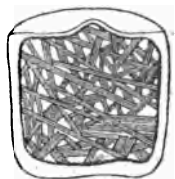
247. What is the composition of cyanogen? How may it be formed? For what is this compound remarkable? What are its compounds called?

248. Has sulphur been long known? Where does it occur as a

found in almost every place. From one of its compounds with iron, called *iron pyrites*, it is procured in large quantities, for the purposes of commerce. It is found, also, in many organic bodies, as in eggs; in the hair, horns, and hoofs of animals, and in the seeds of black mustard.

**249. Properties.**—Sulphur is a brittle solid, of a greenish-yellow color, emits a peculiar odor when rubbed, and has little taste. It is a non-conductor of electricity, and is excited negatively by friction. It fuses at  $226^{\circ}$ , and becomes nearly as liquid as water; but if the heat be raised as high as  $430^{\circ}$ , it becomes so tenacious that the vessel containing it may be inverted without spilling it, and is then of a dark molasses color. When heated to at least  $428^{\circ}$ , and then poured into water, it becomes a ductile mass, which may be used for taking the impression of seals. After some time, it changes into its ordinary state.

Fused sulphur has a tendency to crystalize in cooling. A crystalline arrangement is perceptible in the centre of common roll sulphur; and, by good management, regular crystals may be obtained. For this purpose, several pounds of sulphur should be melted in an earthen crucible; and, when partially cooled, the outer solid crust should be pierced, and the crucible quickly inverted, so that the inner and as yet fluid parts may gradually flow out. On breaking the solid mass, when quite cold, a confused arrangement of prismatic crystals will be found in the interior. Sulphur is dimorphous (205).



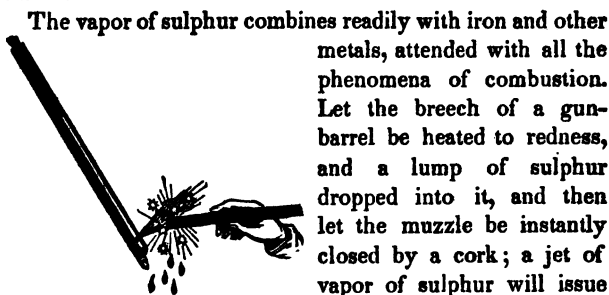
Sulphur is very volatile, and begins to rise in vapor even before it is completely fused. At about  $600^{\circ}$ , it boils, and

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mineral production? In what mineral substances is it found in combination? In what organic bodies?

**249.** Describe some of its properties. How may it be crystal-

the vapor, if in a close vessel, will be condensed on any cold surface, forming the *flowers of sulphur*. The density of its vapor is about 6.65. When vapor of sulphur is brought in contact with vapor of alcohol, they unite; but solid sulphur is quite insoluble in alcohol, or water, but dissolves in boiling oil of turpentine, or in sulphuret of carbon.



The vapor of sulphur combines readily with iron and other metals, attended with all the phenomena of combustion. Let the breech of a gun-barrel be heated to redness, and a lump of sulphur dropped into it, and then let the muzzle be instantly closed by a cork; a jet of vapor of sulphur will issue violently from the touch-hole, which will be inflamed as it enters the air; and a bunch of small iron wire, held in it, will burn freely, forming sulphuret of iron, which will fall in drops.

Sulphur is used extensively in the arts, and in medicine. It is employed in the manufacture of gunpowder, sulphuric acid, the different kinds of matches, vermilion, &c., and for taking impressions of seals. In medicine, it is used in cutaneous diseases, and as a cathartic and alterative.

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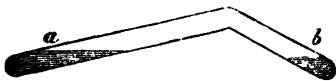
ized? What are the flowers of sulphur? How may sulphur be dissolved in alcohol? Describe the combustion of iron wire by vapor of sulphur.

*Compounds of Sulphur and Oxygen.*

250. Sulphur and oxygen combine in at least four proportions, forming the compounds,  $S_2O_2$ ,  $SO_2$ ,  $S_2O_3$ ,  $SO_3$ , all of which are acids; but only the second and last will be here described.

251. *Sulphurous Acid*— $SO_2$ ; eq.  $(16.1 + 16 =) 32.1$ .—This substance is gaseous at ordinary temperatures, and is the sole product of the combustion of sulphur in the open air, or in dry oxygen gas. It is more conveniently prepared, however, by heating strong sulphuric acid in contact with pieces of copper or mercury. One equivalent of the sulphuric acid gives up one equivalent of its oxygen to unite with the metal, and the oxide thus formed is immediately dissolved by a second atom of the sulphuric acid, while the sulphurous acid passes off as a gas. Thus,  $2 SO_3 + Hg = HgO, SO_3 + SO_2$ .

Sulphurous acid is a dense, colorless gas, 100 cubic inches of which weigh 68.55 grains, giving it a specific gravity of 2.21. It is distinguished from all other gases by its suffocating odor, which every one has recognized in burning sulphur. It is absorbed largely by water, and may be condensed into the liquid form by moderate pressure, or by a cold of zero. A little of the liquid may be obtained very easily, by putting a small quantity of mercury and sulphuric acid in a bent tube, as represented in the figure, sealing it hermetically, and supplying heat to the extremity, *a*, which contains the materials, while the other, *b*,



250. How many compounds of sulphur and oxygen are there? What two only will be described?

251. How may sulphurous acid be prepared? Describe the chemical changes that take place. Describe some of the properties

is kept cool by means of ice, or the evaporation of ether. The liquid will be soon found to collect in the cool part of the tube. Care should be taken not to heat the tube too much, lest it should burst.

Sulphurous acid is much used for bleaching, especially articles of straw; which, in a moist state, are suspended in an atmosphere charged with the gas. For this purpose, the gas is formed by burning sulphur in the air, in some enclosure, as a box or empty cask, in which the articles to be bleached are suspended.

252. *Sulphuric Acid* —  $\text{SO}_3$ ; eq.  $(16.1 + 24 =) 40.1$ . — This acid is always seen as a dense liquid, not unlike oil in appearance; and, having been formerly obtained altogether by the distillation of green vitriol (sulphate of iron), it received the name, *oil of vitriol*, by which it is now often known. It is prepared at the present time, at Nordhausen, Germany, by the same mode. Green vitriol is thoroughly dried by heat, and then distilled, at a high temperature, by which it is decomposed, and the acid passes over and condenses as a brown oil-like liquid, which still contains one eq. of water for every two eq. of the acid. Its composition, therefore, is  $2(\text{SO}_3), \text{HO}$ . Its density is 1.9, or nearly twice that of water. When this liquid is again distilled, at a moderate heat, a dry, silky solid is obtained, which is the pure compound,  $\text{SO}_3$ ; but it possesses no acid properties until water is added, which changes it to common sulphuric acid. This solid has a strong affinity for water, and hisses like a hot iron, when thrown into it.

The common method of preparing the oil of vitriol of

of sulphurous acid. How may it be liquefied? For what purpose is it much used?

252. In what form is sulphuric acid always seen? What is its common name? How is it prepared at Nordhausen, in Germany? How may the dry acid be obtained from this liquid? How is the

commerce is, to burn a mixture of sulphur and nitrate of potash, or soda, in a furnace so contrived that the current of air which supports the combustion conducts the gaseous products into a large leaden chamber, the bottom of which is covered to the depth of several inches with water. Numerous complicated changes take place in the leaden chamber, during the combustion of the sulphur, by which oxygen from the air is transferred to the sulphur, converting it into this acid. The water is designed chiefly to absorb the vapors of sulphuric acid as they are formed; but watery vapor is also necessary in the chemical changes that occur. When the water in the chamber is sufficiently charged with the acid, it is drawn off and concentrated by boiling in a platinum still, as long as its density continues to increase. It has then a specific gravity of 1.84; and its composition is  $\text{SO}_3, \text{HO}$ , and its equivalent,  $(16.1 + 24 + 9 =) 49.1$ .

Sulphuric acid is, perhaps, the most important of all the acids, as by its aid nearly all the others are produced. Its acid properties are very decided; aided by heat, it decomposes animal and vegetable substances, causing a deposition of charcoal, and formation of water, which it absorbs. Its affinity for water is very great, and the combination of the two substances is attended with the production of considerable heat. If a mixture of four parts of the acid and one of water, is stirred with a test-tube containing sulphuric ether, the heat generated will be sufficient to cause the ether to boil.

Uncombined sulphuric acid is occasionally



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common oil of vitriol of commerce prepared? How is the weak acid, thus obtained, concentrated? What is the specific gravity of the common oil of vitriol? What is said of its importance, as compared with the other acids? What is said of its affinity for



found in the water of springs, as at Byron, Genesee County, New York; but such cases are rare.

Sulphuric acid is applied in the arts, and in the laboratory, to very many important uses; as, in the preparation of the other acids, the extraction of soda from common salt, the manufacture of alum, sulphate of iron, chlorine, &c. It is also used as a solvent for indigo, and in the various manufactures of the metals.

### *Compounds of Sulphur and Hydrogen.*

253. There are only two compounds of sulphur and hydrogen known, hydrosulphuric acid (HS) and persulphuretted hydrogen ( $\text{HS}_2$ ). The former, only, will be described.

254. *Hydrosulphuric Acid*—HS; eq.  $(16.1 + 1 =) 17.1$ .—This substance, often called *sulphuretted hydrogen*, is gaseous, and may easily be prepared by the action of diluted sulphuric acid upon sulphuret of iron, formed by intensely heating a bar of iron, and then rubbing it with a roll of sulphur. The chemical changes that take place during the process are as follows:— $\text{FeS} + \text{SO}_3 + \text{HO} = \text{FeO}, \text{SO}_3 + \text{HS}$ .

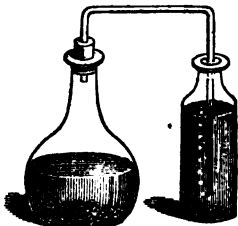
Hydrosulphuric acid is a colorless gas, of most offensive odor, similar to that of putrefying eggs; 100 cubic inches of it weigh 36.49 grains, giving it a density of 1.18. By strong pressure, it is condensed to the liquid form. It is exceedingly poisonous, when taken into the lungs; and a jet of it in the air burns with a feeble, blue flame, producing sulphurous acid and water.

water? What is said of its occurrence in springs? What use is made of this acid?

253. How many compounds of sulphur and hydrogen are known?

254. What is the composition of hydrosulphuric acid? How may it be prepared? Describe the chemical changes that take place. Describe some of its properties. What is said of its ab-

Cold water absorbs its own volume of the gas, and acquires its peculiar odor. *Sulphur-springs*, which occur in many places in New York, Virginia, and other states, are springs, the waters of which are naturally impregnated with hydrosulphuric acid. They may always be recognized by the offensive odor, which extends to a distance around them, and by their blackening pieces of silver coin, by the formation of sulphuret of silver. Water, possessing all the properties of that of the most noted sulphur-springs, may be prepared artificially, by passing a current of this gas, for a few minutes, through cold water. Let a little diluted sulphuric acid be poured upon some powdered sulphuret of iron, in a small bottle, and then insert a cork with a bent tube, as shown in the figure, the other end of which shall dip in a vial of cold water. After the gas has bubbled through it a few minutes, it will be found fully impregnated.



This gas blackens many colorless metallic salts, by the formation of metallic sulphurets. An amusing experiment may be performed in the following manner: Let a picture be traced on white paper with a solution of sugar of lead, which is perfectly colorless, and the picture, at a little distance, will be invisible. Let the back of the paper be now moistened by



sorption by water? What constitutes the water of sulphur springs? How may sulphur springs be recognised? How may sulphur water be prepared artificially? Explain the reason why this gas blackens many colorless metallic salts. Describe the mode of

means of a wet sponge; and, after tacking it to the wall, let a current of this gas be directed against it, and all the parts traced by the lead solution will instantly become dark brown, or black, by the formation of sulphuret of lead on the paper.

### *Compounds of Sulphur and Carbon.*

255. *Bisulphuret of Carbon*— $\text{CS}_2$ ; eq.,  $(32.2 + 6.1 =)$  38.3.—This compound is prepared by heating, intensely, pieces of charcoal in an iron retort, and then dropping in pieces of sulphur, and receiving the gaseous product in a vessel kept cold by ice. It is a dense liquid, of specific gravity 1.27, refracts light powerfully, and has a very offensive odor. It is very volatile, and produces intense cold by its evaporation. It is preserved covered with water, in well-stopped bottles. It is sometimes called *alcohol of sulphur*.

### PHOSPHORUS.

*Symbol, P; Equivalent, 15.7; Density, 1.77.*

256. *History*.—Phosphorus was discovered by an alchemist of Hamburg, in 1669; and received its present name (from *phos*, light, and *pherein*, to carry) from the circumstance that, at ordinary temperatures, it always appears luminous in the dark. It is not found in nature in a separate state; but in combination with oxygen and lime, it is very generally diffused, being contained in all fertile soils, without exception, and in many vegetable and animal substances.

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producing pictures by means of solution of sugar of lead and this gas.

255. How is bisulphuret of carbon prepared? Describe some of its properties.

256. By whom was phosphorus discovered? What is the derivation of the name? Is it found in nature in a separate state?

**257. Preparation.**—Phosphorus, at the present time, is prepared entirely from bones, which are first ignited in the open air until they become white, so as to destroy all the animal matter they contain. More than half their weight remains, which is chiefly phosphate of lime. This is then ground to a fine powder, and digested, for one or two days, with half its weight of sulphuric acid, previously diluted with an equal measure of water. More warm water is then added, and the whole filtered, and the clear liquid thus obtained, evaporated until it begins to be quite thick, when it is mixed intimately with charcoal, in fine powder, and thoroughly dried. It is next

introduced into an earthen retort, *a*, which is placed in a proper furnace, as represented in the figure; and to the neck of the retort, a wide copper tube, *b*, is attached, which connects with a vessel of water. The heat is then gradually raised, when the phosphorus distils over, and is condensed in the water. Much gaseous matter, also, comes



over and escapes by the second tube, inserted in the water-vessel. The phosphorus, thus prepared, may be further purified by melting it under water, and pressing it through porous leather. •

**258. Properties.**—Pure phosphorus is of a light flesh-color, and nearly transparent. At common temperatures, it

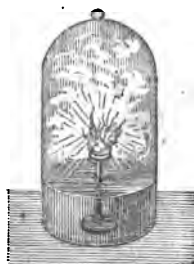
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257. From what is it prepared? What is the chief solid ingredient of bones? Describe the process for procuring phosphorus. How may the phosphorus thus procured be further purified?

258. Describe some of the properties of phosphorus. In what

is a soft solid, of specific gravity 1.77, and may easily be cut with a knife. At  $108^{\circ}$ , it fuses; and at  $550^{\circ}$ , is converted into vapor, which, according to Dumas, has a density of 4.35. It is soluble, by the aid of heat, in naphtha, in fixed and volatile oils, and in some other liquids. By the fusion and slow cooling of a considerable quantity, it may be crystalized.

Phosphorus is exceedingly inflammable. Exposed to the air, at common temperatures, it undergoes slow combustion, emits a white vapor of a peculiar alliaceous odor, appears distinctly luminous in the dark, and is gradually consumed. On this account, phosphorus should always be kept under water. In the open air, even the heat of the hand, aided by the slightest friction, is sufficient to inflame it; and it should therefore always be handled with the greatest caution. It burns in the air with a brilliant, yellowish white light and intense heat; but in oxygen gas, its combustion is particularly splendid. A good method for



performing the experiment is to place a piece of phosphorus on a small stand, a few inches high, in a shallow basin of water; and, having ignited the phosphorus by touching it with a piece of heated wire, dexterously to place over it a large bell-glass, previously filled with oxygen. By careful management, but little of the oxygen will be lost.

It may also be made to burn under warm water, by forcing a current of oxygen upon it by means of a gas-bottle, or a flexible tube, leading from a gasometer. A red suboxide is

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liquids is it soluble? Why does it always appear luminous in the dark, when in the open air? How is it kept? What is said of its combustion in oxygen gas? How may the experiment be per-

formed, which readily takes fire in the open air.

There is some doubt concerning the proper equivalent of phosphorus; by some it is considered to be 15.7, or only half the number we have given above.

Phosphorus is now used in large quantities in the manufacture of friction-matches, which ignite by slight friction. For this purpose it is dissolved in glue, by which it is made to adhere to small pieces of wood or paper previously dipped in melted sulphur, and is also protected from the action of the air. It is of important service in the laboratory, and has been sometimes used in medicine.



### *Compounds of Phosphorus and Oxygen.*

259. There are four compounds of phosphorus and oxygen, the atomic constitution of which appears to be  $P_2O$ ,  $PO$ ,  $PO_2$ , and  $PO_5$ .—The last three are acids; but only one of these, the last, will be described.

260. *Phosphoric Acid*— $PO_5$ ; eq.,  $(31.4 + 40 =) 71.4$ .—This acid is formed by burning phosphorus in air or in oxygen gas, as in the experiment given above (258). To prepare it dry, the receiver should be placed over mercury, and the oxygen or air supplied should be perfectly dry. The acid appears as a dense white vapor, which is gradually precipitated, and may be collected. In the open air it

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formed? How may phosphorus be made to burn under water? What use is made of phosphorus?

259. How many compounds of phosphorus and oxygen are there?

260. What is the composition of phosphoric acid? How may it be formed? How does the acid appear? What will be the

absorbs moisture and is dissolved. If the white flakes are collected and ignited, the mass, after cooling, is semi-transparent, and is called *glacial phosphoric acid*. This acid may also be formed from calcined bones.

The anhydrous phosphoric acid has a very strong affinity for water, and when thrown into it, unites with it with great energy, often producing slight explosions, in consequence of the heat produced. With water, it forms three different compounds, as follows, the first two of which have been called, respectively, metaphosphoric, and pyrophosphoric acids.

|                                                                            |                                 |
|----------------------------------------------------------------------------|---------------------------------|
| Monobasic phosphate of water (metaphosphoric acid),                        | $\text{PO}_4\text{HO}$          |
| Bibasic                   "                   " (pyrophosphoric acid),     | $\text{PO}_4\text{,}2\text{HO}$ |
| Tribasic                   "                   " (common phosphoric acid), | $\text{PO}_4\text{,}3\text{HO}$ |

These three acids, or rather compounds of acid and water, cannot be distinguished from each other by external appearance, but dissolved in water they manifest chemical characteristics which render them quite distinct; they also form salts, which, though much alike in their general properties, are nevertheless easily distinguished from each other by the proper tests.

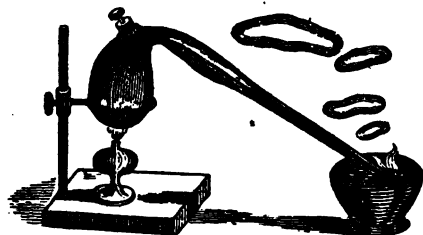
### *Compounds of Phosphorus and Hydrogen.*

261. There are several compounds of phosphorus and hydrogen, but one only will claim attention from us, the common phosphuretted hydrogen,  $\text{PH}_3$ .

effect if it is kept in the open air? What is said of the affinity of this acid for water? What three compounds does it form with water? What is said of the salts which are formed by these several compounds?

261. What is the composition of phosphuretted hydrogen?

262. *Phosphuretted Hydrogen*— $\text{PH}_3$ ; eq.,  $(31.4+3=)$  34.4.—This is a gaseous substance, and is best prepared by heating some sticks of phosphorus in a strong solution of caustic potash, in a small glass retort, which, at the beginning of the operation, should be quite filled with the materials. If then the mouth of the retort is made to dip slightly in a basin of water, each bubble of the gas, as it breaks into the air, will burst into a flame, with the formation of beautiful wreaths of smoke of phosphoric acid, as shown in the figure. It may be prepared by other means, but it does not always, when so prepared, take fire spontaneously in the air. It is a colorless gas, with a very disagreeable odor, and is irrespirable; 100 cubic inches of it weigh 36.75 grains, giving it a specific gravity of 1.18.



## BORON.

*Symbol, B; Equivalent, 10.9; Density, 2.*

263. *History*.—Boron has not been long known; it was first obtained by Davy, in 1807. It is contained in the substance called *borax*, in which it is combined with oxygen and soda. Borax is found in solution in the water of certain mineral springs, chiefly in volcanic countries.

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262. How may it be prepared? What is the effect when bubbles of this gas escape in the air? What is said of its odor?

263. When and by whom was boron discovered? In what well-known substance is it contained?



264. *Preparation.*—For ordinary experiments, boron may be prepared, of sufficient purity, by heating well-dried borax in fine powder with one tenth of its weight of charcoal in a gun-barrel, and washing the powder obtained with diluted hydrochloric acid.

265. *Properties.*—Boron is a dark olive-green powder, without taste or smell, and incapable of fusion in the strongest heat. It is insoluble in water or alcohol. Heated in the open air to about  $600^{\circ}$ , it takes fire and burns brilliantly.

### *Compound of Boron and Oxygen.*

266. *Boracic Acid*— $\text{BO}_3$ ; eq.,  $(10.9 + 24 =) 34.9$ .—This is the only compound of boron and oxygen that is known. It is always produced when boron is burned in the air, and is found native in the waters of some mineral springs in volcanic regions. It may also be obtained as a white solid, in shining scales, by decomposing a hot solution of borax by sulphuric acid. This is done by pouring the sulphuric acid gradually into the heated solution, and stirring until it begins to taste acid;—after cooling a few minutes, the shining scales of boracic acid will be seen to precipitate.

Boracic acid is scarcely soluble in water, but dissolves readily in alcohol; and when the solution is inflamed it communicates to the flame a beautiful green tinge, which is characteristic of this substance. To make the experiment,

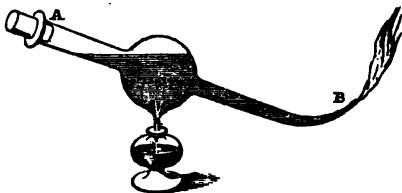
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264. How may it be prepared?

265. Describe the properties of boron.

266. Of what is boracic acid composed? Describe the mode of obtaining it from borax. Is it soluble in water? What is said of its solution in alcohol?

fill a common dropping tube, of the form AB in the figure, with the solution; and, inserting a cork firmly in A, apply the heat of a lamp to the bulb, and inflame the jet of liquid as it issues from the capillary orifice, B. The flame will be of a beautiful green.



## SILICON

*Symbol, Si; Equivalent, 22.2; Density, ?.*

267. *History*.—Silicon was first obtained by Berzelius, in 1824. It was then considered a metal, and named *silicium*, but is now universally ranked with the non-metallic elements. It is never found in its separate state in nature, although it is really very abundant in every place in silicic acid (silica), and the various siliceous compounds which constitute the rocks and soils.

The mode of preparing it is too complex and difficult to require description in so elementary a work as the present.

268. *Properties*.—Silicon, as usually prepared, is a dark nut-brown powder, quite insoluble in water, and incapable of fusion in the strongest heat. Heated in the open air, it burns freely, provided it has not before been subjected to heat in a close vessel, in which case it becomes combustible.

267. By whom was silicon first obtained? What is said of its abundance in nature?

268. What are some of its properties?

*Compound of Silicon and Oxygen.*

269. *Silicic Acid*, or *Silica*— $\text{SiO}_2$ ; eq.,  $(22.2 + 24 =)$  46.2.—This is one of the most abundant substances in nature, and is found quite pure in quartz, flint, calcedony, agate, &c.; and, in combination with other substances in the material of all soils, and nearly all rocks. It requires a very high temperature for fusion. In its ordinary state it shows no acid properties, but heated with the alkalies and other bases it readily unites with them, forming salts, some of which are soluble, but most of them are quite insoluble. It appears to exist in two states, in one of which it is partially soluble in acids, and even in water, but in the other state it is quite insoluble.

Silica is applied in the arts to several important purposes, as in the manufacture of glass and porcelain ware. Mixed with hydrate of lime it constitutes common mortar, but united with it in certain proportions, in the form of clay, it constitutes *water-cement*, which, when made into mortar, is capable of hardening under water.

## SELENIUM.

*Symbol*, Se; *Equivalent*, 39.6; *Density*, 4.32.

270. *History*, &c.—Selenium was discovered, in 1818, by Berzelius, and received its name from *selene*, the moon. It is usually found associated with sulphur, in some of its compounds with other substances, especially sulphuret of iron (iron pyrites). In mass it resembles lead, but in pow-

269. In what is silicic acid, or silica, found nearly pure? What use is made of silica in the arts?

270. With what is selenium usually found associated? What are some of its properties?

der it has a chocolate color. It is insoluble in water, and suffers no change in the air, unless it is heated, when it burns freely, forming compounds with oxygen resembling those of sulphur with oxygen. In close vessels it sublimates at about  $650^{\circ}$ .

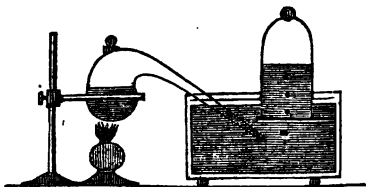
When heated in the open air it exhales a strong odor, resembling decayed horse-radish,—a character by which it may always be distinguished.

## CHLORINE.

*Symbol, Cl; Equivalent, 35.4; Density, 2.47.*

**271. History.**—Chlorine was discovered by Scheele, in 1774, and for many years was regarded as a compound, but its true character, as a simple element, is now universally admitted. It is not found uncombined in nature, but is abundant in its compounds, especially common salt, which is so generally distributed over the surface of the earth. It receives its name from the Greek *chloros*, green, because of its yellowish-green color.

**272. Preparation.**—Chlorine gas is easily prepared by pouring strong hydrochloric acid upon half its weight of peroxide of manganese in a glass retort, and applying a gentle heat. It may be collected over warm water, but not without some being absorbed by it. The following formula indicates the changes that take place:—

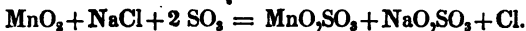


271. By whom was chlorine first discovered? Is it ever found in nature uncombined? From what is the name derived?

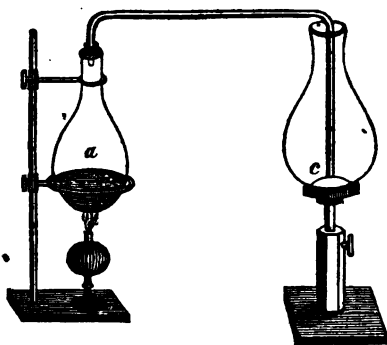
272. Describe the mode of preparing it.



A cheaper process, and nearly as convenient, is to mix, intimately, three parts of common salt with one of the peroxide, and pour over it two parts of sulphuric acid, previously diluted with an equal weight of water. In this case,



**273. Properties.**—Chlorine is a dense gas, of a yellowish green color, as above stated, and has an astringent taste, and rather disagreeable odor. By a pressure of four atmospheres, it may be compressed into a liquid. The weight of 100 cubic inches is 76.59 grains, which gives a density of 2.47. Cold water absorbs it readily, so that the gas cannot be collected over it without great loss; but, in conse-



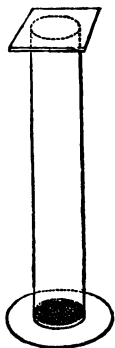
quence of its great specific gravity, it may be collected in an open vessel, by direct displacement of the air. Let *a* be the flask containing the materials, and *c* a receiver in which the gas is to be collected, the tube from the flask extending

nearly to the bottom. The chlorine gas being so much heavier than air, fills up the receiver just as water would if conveyed into it in the same manner; and if the process is expeditiously conducted, the chlorine may be collected nearly pure.

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**273.** Describe some of the properties of chlorine. Describe the mode of collecting it by displacement of the air. Will chlorine

Chlorine is allied to oxygen in many of its properties; a lighted candle continues to burn in it for a time, and phosphorus and some of the metals, if in thin leaf or fine powder, take fire in it spontaneously. For this purpose, a tall jar should be used, as represented in the figure; and the bottom should be covered with sand, to prevent the breaking of the glass by the heated chloride falling upon it. It has a strong affinity for hydrogen, and a mixture of the gases explodes by the approach of flame, and by the electric spark, precisely as a mixture of oxygen and hydrogen. If a piece of paper, moistened with oil of turpentine, be suspended in a bottle of chlorine, it takes fire spontaneously, by the chlorine combining with the hydrogen of the turpentine; at the same time the carbon of the turpentine is liberated, in a state of minute division, as a dense black smoke. The bottle containing the chlorine should have a large mouth.



One of the most important properties of chlorine is its bleaching power, all vegetable and animal coloring matters being speedily destroyed by it. Powdered indigo, slightly moistened and dropped into a bottle containing it, even if it is considerably diluted with air, soon loses its color entirely; and pieces of calico, of different colors, suspended in it, are affected in the same manner, without, in the least, injuring the texture of the cloth. It is therefore much used in preparing rags

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support combustion? How may some of the metals be made to take fire in it spontaneously? What is said of its affinity for hydrogen? Describe the experiment with a piece of paper moistened with oil of turpentine. What is said of the bleaching power

for the manufacture of writing-paper, and also in bleaching cotton and linen goods. Writing done with common ink is easily removed by it; but printers' ink, being an oily preparation, is not attacked by it.

Chlorine is also a powerful disinfecting agent, removing at once all offensive effluvia from sewers, vaults, and other places where they may have collected. For this purpose, bleaching-powder (to be described hereafter) is moistened with water, and placed in shallow dishes in the apartments to be fumigated.

### *Compounds of Chlorine and Oxygen.*

274. The compounds of chlorine and oxygen are four in number, as follows, viz:— $\text{ClO}$ ,  $\text{ClO}_2$ ,  $\text{ClO}_3$ , and  $\text{ClO}_4$ , all of which are acids; but as the affinities of these substances for each other are very feeble, their compounds are all decomposed by slight causes.

275. *Hypochlorous Acid*— $\text{ClO}$ ; eq.,  $(35.4 + 8 =) 43.4$ .—This is a gaseous substance, of a yellowish-green color, like that of chlorine, but a shade deeper. It exists in combination with lime in the common *bleaching-powder*.

276. *Chlorous Acid*— $\text{ClO}_2$ ; eq.,  $(35.4 + 32 =) 67.4$ .—This compound is also gaseous, and of a deep yellowish color. It is formed by the action of sulphuric acid upon chlorate of potash. If a few grains of chlorate of potash are placed in a wine-glass, and a little sulphuric acid poured in, the glass will be soon filled with the gas, which will be recognized by its color. If now a rag, wet with oil of tur-

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of chlorine? What is the mode of using it as a disinfecting agent?

274. How many compounds of chlorine and oxygen are there?

275. Describe hypochlorous acid.

276. Describe chlorous acid.

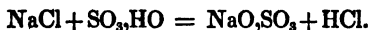
pentine, be presented to it, on the end of wire or a stick, it will be inflamed, and the gas at the same time exploded.

277. *Chloric Acid*— $\text{ClO}_3$ ; eq.,  $(35.4 + 40 =) 75.4$ .—Chloric acid is obtained by passing a current of chlorine through a strong solution of potash, with which it combines as it is formed, producing chlorate of potash. By evaporating the solution, this salt may then be obtained in small, shining crystals.

278. *Perchloric Acid* possesses no characters that render it of any special interest.

### *Compound of Chlorine and Hydrogen.*

279. *Hydrochloric Acid*— $\text{HCl}$ ; eq.,  $(35.4 + 1 =) 36.4$ .—This is the only known compound of chlorine and hydrogen; and, in solution in water, has long been used in the arts, under the names of *muratic acid*, and *spirit of salt*. It is formed by the action of diluted sulphuric acid upon common salt. The sulphuric acid should be diluted with about an equal weight of water, and be allowed to cool before being used. The changes which take place are as follows:—



It is also formed by the direct union of its elements. When equal measures of chlorine and hydrogen are mixed together, and an electric spark is passed through the mixture, instantaneous combination takes place, heat and light are emitted, and hydrochloric acid is generated. A similar effect is produced by flame, by a red-hot body, and by

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277. How is chloric acid formed?

279. By what other names is hydrochloric acid often known? From what is it formed? Describe the chemical changes that take place. May it be formed by the direct union of its elements?



spongy platinum. Light also causes them to unite. A mixture of the two gases may be preserved, without change, in a dark place; but if exposed to the diffused light of day, gradual combination ensues, which is completed in the course of twenty-four hours. The direct solar ray, like flame and the electric spark, produces an explosion by a sudden inflammation of the whole mixture; but to insure the success of the experiment, the gases should be very pure, and the chlorine recently prepared over warm water. The glass vial containing the mixed gases, after being filled, should be instantly covered with a black cloth, which can be suddenly removed by a stick, or wire, after it is placed in the sun's rays.

Hydrochloric acid is, of course, a chloride of hydrogen. When pure it is a colorless gas, of which 100 cubic inches weigh 39.38 grains, giving it a density of 1.27. By strong pressure it may be compressed into a liquid. It is quite irrespirable, and incapable of supporting combustion. Water absorbs it with avidity, taking up, under favorable circumstances, no less than 480 times its own volume. During the absorption it increases considerably in volume, and the saturated solution has a density of 1.21, and contains about forty-two per cent. of the acid. In the open air, copious fumes of the gas constantly arise from the liquid, which produce a cloud of smoke if any ammonia be present in the air. Thus, let a little aqua ammoniæ (230) be poured into a glass vessel, A, with a large mouth, and then invert over it a tumbler, the inside of which has been thoroughly moistened with common hydrochloric acid. The



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What is the effect of light upon the mixed gases? What are some of the properties of hydrochloric acid? What is said of its absorption by water? What occasions the fumes when ammonia and hydrochloric acid gases come in contact?

two gases, coming in contact, unite, and fill both glasses with a dense, white smoke, which is solid hydrochlorate of ammonia (189), in a finely divided state.

280. *Aqua regia*, so called because of its ability to dissolve gold and platinum, is a mixture of two parts of hydrochloric to one of nitric acid. Let a single leaf of gold be placed in a wine-glass containing a little hydrochloric acid, and another leaf in a separate glass with some nitric acid; the gold will remain undissolved in both glasses for any length of time; but, on mixing the contents of the glasses, the whole of the gold will be speedily dissolved. The real solvent in this case is the chlorine, which is liberated by the action of the acids upon each other.

Liquid hydrochloric acid is extensively used for various purposes in the arts, and is one of the most important chemical agents of the laboratory.

Chlorine forms compounds with the other elements, nitrogen, carbon, sulphur, &c., which have been described, but they do not possess sufficient interest to require notice here.

X

IODINE.

*Symbol, I; Equivalent, 126.5; Density, 4.95.*

281. *History*.—Iodine (from *iodes*, violet color) was discovered in the ashes of sea-plants, from which it is still prepared, by M. Courtois of Paris, in the year 1812. It is found also in certain ores of silver and zinc, in sea-water, and in the water of certain mineral springs.

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280. What is aqua regia? Will hydrochloric or nitric acid alone dissolve gold leaf? What use is made of liquid hydrochloric acid? Does chlorine unite with nitrogen, carbon, and sulphur?

281. From what is iodine prepared?

282. *Preparation*.—As stated above, the iodine of commerce is obtained from the ashes of sea-plants, especially the *fucus palmatus*. The ley obtained by lixiviating the ashes is first evaporated, to separate a portion of the salts it contains, and the residue is then mixed with peroxide of manganese and sulphuric acid, and a gentle heat applied, when the iodine distils over, as a beautiful violet-colored vapor, into a receiver prepared for the purpose, where it is condensed.

283. *Properties*.—Iodine, at ordinary temperatures, is a soft, friable, nearly black solid. Usually it is in small shining crystals, which have a metallic lustre, and a density of 4.95. Heated a little above  $212^{\circ}$ , it melts, and is thus converted into a beautiful violet-colored vapor, which has a density of 8.70 (air being 1), and 100 cubic inches weigh 270.1 grains. Iodine is a non-conductor of electricity and heat, and is allied to oxygen and chlorine in many of its properties. Its odor resembles that of chlorine, but is less offensive. It is sparingly soluble in water, requiring about 7000 times its own weight of this liquid for complete solution; but alcohol and ether dissolve it freely, forming a deep brown solution. A few of the crystals pressed upon the skin produce a deep stain, which however soon disappears.

Starch affords a delicate test of iodine, forming with it a beautiful blue. The starch should be prepared by dissolving it in hot water, and allowing it to cool before using. Let a little hot water be poured upon ashes obtained by burning a piece of sponge, and, after filtering, add a drop or two of solution of starch; then pour in a few drops of sulphuric acid, which will settle to the bottom, and almost always

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282. Describe the mode of preparing iodine.

283. What are some of its properties? Is it soluble in water? How may starch be used as a test for iodine?

the blue color will be observed, indicating the presence of iodine.

Iodine has not been much used in the arts, but is largely employed in medicine. In the Daguerreotype process (124), it is essential; and recently it is said to have been employed in dyeing.

*Compounds of Iodine and Oxygen, Hydrogen, &c.*

284. Iodine and oxygen combine in two proportions, producing iodic ( $\text{IO}_5$ ) and periodic ( $\text{IO}_7$ ) acids; neither of which however possesses any special interest.

285. *Hydriodic Acid* (iodide of hydrogen) is a gaseous substance, of a specific gravity 4.39, and in many of its properties strongly resembles the corresponding chloride of hydrogen (hydrochloric acid).

*Iodide of phosphorus* is formed by bringing the two substances together in a vessel where as little air may have admission as possible. It forms a dark-colored mass. These two substances afford one of the few instances in which reaction takes place between two solids. Let a few crystals of iodine be dropped into a wine-glass, upon a small piece of phosphorus, and immediately place over it a bell-glass. By the heat produced, the phosphorus will be inflamed and a portion of the iodine sublimed; and the white cloud of phosphoric acid (260), mingling with the dense iodine vapor, presents to the eye a very pleasing appearance.



Chlorine combines readily with iodine, forming a chloride, which has been much used in the Daguerreotype process, in preference to pure iodine.

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285. Describe hydriodic acid. How may iodide of phosphorus be formed?

## BROMINE.

*Symbol, Br; Equivalent, 78.3; Density, 3.*

286. *History.*—Bromine was discovered in 1826, in seawater; and received its name, *bromine* (from *bromos*, offensive odor), in consequence of its exceedingly disagreeable smell. Recently it has been obtained in large quantities from the waters of some of the salt-springs in Pennsylvania and Virginia.

287. *Preparation.*—The usual mode of preparing bromine is a little complex. First, the brine from the spring is evaporated, and the common salt removed by crystallization, then the mother-liquor, or *bittern*, as the uncrystallizable residue is called, is treated with a current of chlorine, and sulphuric ether afterwards added, by which the bromine that has been separated from its compounds by the chlorine is taken up, and rises to the surface as a solution of bromine in ether. To obtain it perfectly pure, it is then treated with caustic potash, heated to dryness, and distilled with peroxide of manganese and sulphuric acid.

288. *Properties.*—Bromine is a liquid of a blackish-red color, with a specific gravity nearly 3. At a temperature a little below zero it is frozen, and boils at about  $115^{\circ}$ , forming a vapor of a beautiful blood-red color. It stains the skin yellow, like iodine, but less intensely. Vapor of bromine ignites phosphorus spontaneously, and a lighted candle burns in it a short time.

Bromine is used to some extent in the Daguerreotype process, usually in connection with iodine.

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286. When was bromine discovered? From what is it obtained?

287: What is the mode of preparing it?

288. What are some of its properties?

*Compounds of Bromine.*

289. Bromine combines with oxygen, hydrogen, &c., forming compounds exceedingly analogous to the corresponding compounds of chlorine and iodine.

## FLUORINE.

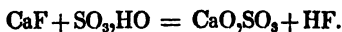
*Symbol, F; Equivalent, 18.7; Density, 1.29.*

290. *History and Properties.*—Fluorine has long been known to exist, but it has not, until recently, been obtained in a separate state. It is found in nature in considerable abundance in the mineral called *fluor spar*, which is a compound of this substance with calcium, the metallic base of lime. It is a brownish-colored gas, of specific gravity about 1.29, and bleaches like chlorine.

*Compounds of Fluorine.*

291. Fluorine seems to be incapable of uniting with oxygen, but combines with hydrogen, forming the acid compound HF.

292. *Hydrofluoric Acid.*—HF; eq.,  $(18.7 + 1 =) 19.7$ .—This acid is formed by subjecting powdered fluor spar, moistened with strong sulphuric acid, to a very gentle heat in a leaden vessel. The acid distils over as a pungent, corrosive, vapor, but may be condensed in a metallic receiver, that is kept surrounded with ice. The chemical changes of the operation are as follows:—




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290. From what substance is fluorine obtained?

292. How may hydrofluoric acid be obtained? Describe its

As thus formed, the acid has a density of 1.07, and manifests a strong affinity for water, with which it combines with great energy. It attacks glass powerfully, combining with its silica, and may therefore be used to etch it. This is done by spreading a thin coat of bees'-wax or varnish upon the glass, and tracing the design upon it, taking care to cut quite through the wax. The liquid acid is now poured over the coated surface, or it is exposed a few minutes to the acid vapor, and the wax afterwards removed.

This acid attacks animal substances powerfully, and, therefore, should always be handled with great care.

Fluorine unites also with boron, and recently it has been announced that it has been combined with iodine and bromine.

## METALLIC ELEMENTS.

### GENERAL PROPERTIES OF THE METALS.

293. The metals are generally good conductors of electricity and heat, and possess a peculiar lustre called the metallic lustre, which can scarcely be imitated by other substances. When their compounds are decomposed by the galvanic battery, they always make their appearance at the negative electrode (154), and are therefore, without exception, to be considered as electro-positive. But these properties are much more distinct in some metals than in others. Most of the metals are also characterized by their

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properties. How may etching be done with it upon glass? How does it affect animal substances?

293. What are some of the properties by which the metals are generally distinguished? What is said of their density? How

great density, as gold and platinum; but two at least, potassium and sodium, are lighter than water.

The ancients were acquainted with only seven metals, viz.: gold, silver, iron, copper, mercury, lead, and tin; but there are now known, with certainty, forty-two; and the discovery of several others (177) has been announced, though perhaps not fully proved.

The metals differ much in their other properties as well as in those already referred to. Some of them are very malleable, and may be beaten into exceedingly thin leaves, while others possess this property, but in a less degree, and others still are very brittle. Gold is noted for its malleability, while antimony, arsenic, and bismuth are so brittle that they can easily be pulverized in a mortar. The malleable metals are usually also very ductile, and admit of being drawn out into fine wire; but the two properties of malleability and ductility are evidently distinct. Iron cannot be beaten into thin leaves, but it may be drawn into very fine wire. In many of the metals these properties vary with the temperature. Iron is not very malleable when cold, but becomes so at a red heat; while brass is quite malleable at low temperatures, but is brittle when heated. Zinc is most malleable at about  $300^{\circ}$ ; at temperatures considerably above or below this, it is brittle. By hammering, and also in the process of wire-drawing, the density and the hardness of the metals are increased, but their original state is restored by the process of *annealing*, which consists in heating them to redness and allowing them to cool slowly.

The metals differ essentially in their fusibility; while

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many were known to the ancients? How many are now known? Do they differ essentially in their properties? What is said of their malleability, ductility, brittleness, &c? What is the effect upon their density by hammering? What is meant by annealing them? Do the metals differ in fusibility? May any of them be



mercury melts at  $-39^{\circ}$ , potassium at  $136^{\circ}$ , tin at  $442^{\circ}$ , and zinc at  $773^{\circ}$ , it requires a heat of about  $2000^{\circ}$  to melt gold, silver, and copper; and platinum and pure iron cannot be melted in the hottest furnace. Some of them, as mercury, arsenic, cadmium, and zinc, are easily volatilized, and may be distilled like water. In cooling from fusion, some of them crystalize, as bismuth, antimony, and zinc; while others, as gold and copper, manifest little of such a tendency.

The metals are all considered as elementary substances, and yet a curious relationship exists among some of them, the reason of which has not been explained. Thus, the equivalents of iridium and platinum are absolutely the same (98.8), and that of osmium (99.7) is but little different, and that of gold (199.2) about double. Other similar groups might easily be pointed out. Most of them, as iron, zinc, and lead, are usually found in the earth, combined with other elements, and are said to be *mineralized*; while a few, as platinum and gold, are obtained in their separate metallic state, and are said to be found *native*. The union of two or more metals produces an *alloy*; but if one of them is mercury, the alloy is called an *amalgam*. They also differ very essentially in their chemical relations; but the important peculiarities of each will be described under the appropriate head.

294. The metals have been variously classified by different writers; but the following arrangement into six orders or groups will probably answer our purpose as well as any we can adopt.

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volatilized by heat? Are they to be considered as simple substances? When is a metal said to be found native? What is an alloy? What is an amalgam?

294. Into what six groups may the metals be divided?

1. Metals, the oxides of which are alkalies.
2. Metals, the oxides of which are alkaline earths.
3. Metals, the oxides of which are earths.
4. Metals which, at a red heat, decompose the vapor of water, but are not acted upon by liquid water.
5. Metals which are incapable of decomposing water, and whose oxides are not reduced by the mere action of heat.
6. Metals whose oxides are reduced by a red heat.

These six groups may be considered as forming two classes, the oxides of the metals in the first three being alkalies or earths, while the oxides of those of the last three are neither alkalies nor earths.

295. *Saline Compounds, or Salts.*—We use the term salt to designate a substance which is composed of an acid and a base; that is, a salt is a compound of two other compounds previously formed. Thus, sulphate of soda is a compound of sulphuric acid (trioxide of sulphur) and oxide of sodium; and so of other salts. It is therefore a double oxide, as nearly all the compounds are which we shall have occasion to describe as salts; but there may also be double chlorides, double sulphurets, double iodides, &c., which it is now agreed may properly be considered as salts. Common salt, which, as we shall soon see, is chloride of sodium, is therefore excluded from the salts; but to avoid this result, many eminent chemists make two classes of salts, placing many of the simple chlorides, iodides, &c., under this head, in addition to the salts proper, according to the above definition.

In larger works a separate chapter is usually devoted to the salts; but as they all have metallic compounds for their

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295. What is a salt? How is this illustrated by sulphate of soda? May a double sulphuret, double chloride, or double iodide, &c., be considered as a salt? Does common salt properly belong to this class?

bases, and most of them oxides of the metals, they may, with great propriety, be described in connection with the metals. In proceeding, therefore, with this class of elements, we shall first describe a metal, then its binary compounds with other elements, and lastly, the more important of the salts of which any of its compounds may constitute the bases.

GROUP I.—METALLIC BASES OF THE ALKALIES.

POTASSIUM.

*Symbol*, K (*Kalium*); *Equivalent*, 39.2; *Density*, 0.865.

296. *History*.—Potassium was first obtained by Sir H. Davy in 1807, from potash, of which it is the base. He procured it by subjecting a stick of caustic potash to the action of a powerful galvanic current, when oxygen made its appearance at the positive, and the metal potassium at the negative, electrode. Previous to this time, potash and the other alkalies and earths had been considered as simple substances. Potassium, in combination with oxygen and other bodies, is very generally diffused in the rocks and soils of every place, but is never found in nature in a separate state. It is contained in most vegetable and many animal substances.

297. *Preparation*.—This metal is best prepared by heating intensely dry carbonate of potash mixed intimately with half its weight of fine charcoal-powder and iron-filings. The potash, being an oxide of potassium, at a high temperature yields its oxygen to the charcoal and iron, and itself distils over into a receiver prepared for the purpose. The

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296. By whom was potassium first obtained? By what mode?

297. How is potassium now prepared?

process is not a little difficult, and the young experimenter will probably find it cheaper to purchase potassium at two dollars per dram (the usual price) than to prepare it.

298. *Properties.*—Potassium is a solid, in color and lustre much resembling lead. At  $150^{\circ}$  it melts, and at a red heat may be distilled in vessels void of gases capable of combining with it. It is the lightest metal known, having a density of only 0.865, and floats upon the surface of water. But its most characteristic property is its affinity for oxygen;—when thrown upon the surface of water it absorbs the oxygen so rapidly as to be inflamed, and burns with a beautiful rose-colored flame. In the open air, the freshly-cut surface absorbs oxygen so rapidly as to be tarnished instantly; and heated even in carbonic acid it takes fire and burns by absorbing the oxygen. In consequence of its affinity for oxygen it can be preserved only in tubes hermetically sealed, or under some liquid that does not contain oxygen, as naphtha, which is found to answer the purpose well.



### *Binary Compounds of Potassium.*

299. *Protoxide of Potassium*— $\text{KO}$ ; eq.,  $(39.2 + 8 =) 47.2$ .—This is *potash*, or *potassa*, and is always formed when the metal is exposed in the open air, or acted on by water. In the latter case, the potash formed is immediately dissolved by the water, as will be found by applying the usual tests. Pure potash is a white, inodorous substance,

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298. Describe the metal potassium. How is it affected by being kept in the air? What is the effect of throwing it upon water? How only can it be preserved?

299. What is potassa, or potash? How is it formed from po-

with a pungent, caustic, taste, and very soluble in water. It absorbs carbonic acid and water rapidly from the air, and should therefore be kept in close bottles.

Pure potash, or rather *hydrate* of potash, called usually *caustic potash*, is prepared for use in medicine and in the arts by decomposing the carbonate of potash by lime. For this purpose, *pearlash* (which is a carbonate of potash) is dissolved in ten times its own weight of water, and half its weight of recently-slaked lime mingled with it, and the whole boiled briskly for half an hour, and then allowed to settle, when the clear liquid is drawn off. This is then evaporated nearly to dryness and poured upon a marble slab; and after cooling is broken in pieces and preserved in close bottles for use. To insure perfect purity, it may be again dissolved in absolute alcohol, and the solution filtered and evaporated as before. The substance thus obtained is *hydrate* of potash, which will stand the most intense heat without giving up its water.

300. Caustic potash attacks the fats and oils with avidity, forming with them the well-known compound, *soap*. It combines also with all the acids, which it neutralizes perfectly. Like the other alkalies, it changes most of the vegetable blues to green, and the turmeric yellow to brown.

301. *Iodide of Potassium* (KI) is formed by heating potassium in contact with iodine; and also by digesting iodine in a hot solution of caustic potash, and exposing the mass, when dry, to a red heat, and subsequently crystalizing from solution in water or alcohol. It is a white solid, very soluble in water, usually seen crystalized in cubes, and is often sold under the name of *hydriodate of potash*.

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tassium? What are some of the properties of potash? How is caustic potash prepared for use in medicine and the arts?

300. What does potash form with the fats and oils?

301. How is iodide of potassium formed?

302. *Sulphuret of Potassium* may be formed by gently heating a mixture of sulphur and pearlash; there are no less than five (and perhaps seven) of these sulphurets, containing, respectively, one, two, three, &c., equivalents of sulphur combined with one of the metal. The tersulphuret was formerly used in medicine under the name of *hepar sulphuris*. Potassium forms compounds also with carbon, nitrogen, phosphorus, bromine, fluorine, &c.; but they are not described in this work.

### *Salts of Potash.*

303. *Carbonate of Potash* ( $\text{KO}, \text{CO}_2$ ).—Carbonate of potash, or *pearlash*, is prepared for the purposes of commerce by leaching the ashes of forest trees, and evaporating the solution thus obtained to dryness, and then heating the dry mass to redness for a time in open vessels, to burn out the combustible matter which is contained in it. As thus procured, it is a white spongy mass, very caustic to the taste, and absorbs moisture rapidly from the air, so that it must be kept in close vessels. It is very soluble in water, but insoluble in alcohol, and is easily fused at a red heat. It is very impure, being mixed with silica and other substances. It is manufactured in large quantities in the United States, in the Canadas, and in Russia.

The article sold as *potash* is the same as the above, except that it is not subjected to the last process of calcination. It is a dark-colored mass, and contains much caustic potash, as well as carbonate, and is used extensively for the manufacture of soap. Pearlash is employed in the manufacture of glass and paints, and for various other purposes.

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302. How may sulphuret of potassium be formed?

303. What is the common name of carbonate of potash? From what is it obtained?

**304. Bicarbonate of Potash ( $\text{KO}_2\text{CO}_2 + \text{HO}_2\text{CO}_2$ ).**

This salt is prepared by subjecting pearlash, for some time, to an atmosphere of carbonic acid, which is absorbed in large quantity. Though less caustic to the taste than pearlash, it is still highly alkaline. It is less soluble also than pearlash, and less deliquescent. This salt is extensively used by bakers under the name of *sal-aratus*.

**305. Nitrate of Potash ( $\text{KO}_2\text{NO}_3$ ).**—This salt, the *saltpetre*, or *nitre*, of commerce, is formed, in this country, by decomposing the nitrate of lime, which abounds in the caverns of some of the western states, by carbonate of potash, and filtering and evaporating the solution thus obtained. In some parts of Europe it is prepared in nitre-beds, which are made by heaping together old mortar, refuse animal matter, wood-ashes, &c., in which it gradually forms by the action of the atmosphere.

Nitrate of potash is usually seen in long six-sided prisms. It is a colorless salt, of a cooling saline taste, and is very soluble in water. Heated to redness, it first melts and is then decomposed, giving off, at first, pure oxygen (209), and afterwards, if the heat is increased, nitrogen and nitric oxide. Thrown on burning charcoal it is decomposed, producing violent deflagration, by which it may always be distinguished from sulphate of soda, for which it has sometimes been mistaken. It is a powerful antiseptic, and is used with common salt in the preservation of meat and other substances.

But the chief use of nitre in the arts is in the manufacture of *gunpowder*, which is composed of nitre six parts, and charcoal and sulphur each one part, the whole being moist-

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304. How is bicarbonate of potash formed? What is the name by which it is familiarly known?

305. How is nitrate of potash obtained? What is its common name? Describe some of its properties. What use is made of it?

ened and thoroughly ground together, and subsequently grained. When fired, the nitre, by its decomposition, furnishes oxygen, which combines the carbon, the sulphur at the same time uniting with the potassa. The action of gunpowder depends upon its generating, when decomposed, a large quantity of gaseous matter at a high temperature. The gases are chiefly nitrogen and carbonic acid, which, at the moment of explosion, occupy more than 1000 times the volume of the powder from which they are formed. The formation of the gases is not instantaneous, but occupies a certain time, and the ball is forced from the gun with a velocity due to the ultimate effect of the whole. When made for particular purposes, the proportion of the ingredients is sometimes considerably varied.

306. *Chlorate of Potash* ( $\text{KO}, \text{ClO}_3$ ).—This salt is formed, together with chloride of potassium, by passing a current of chlorine through a strong solution of pearlsh. The chlorate, being much less soluble than the chloride, readily crystalizes out of the solution, and is obtained in shining white scales. Its taste is not unlike that of nitre, but it is much less soluble than that salt. Heated moderately, it melts, and at a red heat is decomposed (209), giving up the whole of its oxygen. Thrown on burning charcoal, it de-flagrates like nitre, but more energetically. A few of the crystals, wrapped in tin-foil, with a piece of phosphorus, or a little sulphur, explode violently by a blow from the hammer. It was formerly used in the manufacture of Lucifer matches, and has been substituted for nitre in gunpowder; which, however, when thus prepared, is liable to explode from causes so slight that its manufacture is dangerous.

307. *Silicates of Potash. Glass.*—Silica, or silicic acid,

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308. How is chlorate of potash formed? Describe it.



combines with potash in several proportions when the two substances are fused together; if carbonate of potash is used, the carbonic acid is expelled during the operation. Common crown-glass, for windows, is made by fusing together fine clean sand and pearlash; and flint-glass, by using the same materials, with the addition of red lead. In some kinds of glass, soda, or soda and lime, may be substituted for the potash. Dark bottle-glass is made of the same materials as the other kinds, but in a very impure state. *Soluble glass*, as it has been called, because of its being soluble in water, is made by fusing together one part of silica and two or more parts of pearlash (or soda); but if the proportions of the ingredients be reversed, common glass is produced, which is not affected by water.

Solution of *soluble glass* has been used as a varnish to protect combustible bodies from fire.

## SODIUM.

*Symbol*, Na (*Natron* ; *Equivalent*, 23.3 ; *Density*, 0.972.

308. *History and Preparation*.—Sodium was discovered in 1807, by Davy, a few days after the discovery of potassium. The first portions of it were obtained by means of galvanism; but it may be procured in much larger quantity by chemical processes, precisely similar to those just described for obtaining potassium.

309. *Properties*.—Sodium has a strong metallic lustre, and in color is very analogous to silver. It is so soft at

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307. What is glass? How is crown-glass made? How flint glass? How is soluble glass formed? What use has been made of it?

308. By whom was sodium discovered? How is it prepared?

309. Describe its properties. How is it affected when thrown upon water?

common temperatures, that it may be formed into leaves by the pressure of the fingers.

Sodium soon tarnishes on exposure to the air, though less rapidly than potassium. Like that metal it is instantly oxydized by water, hydrogen gas in temporary union with a little sodium being disengaged. When thrown on cold water, it swims on its surface and is rapidly oxydized, though in general without inflaming; but with hot water it scintillates, or even takes fire, and burns with a beautiful yellow flame, which readily distinguishes it from potassium. It is preserved in naphtha in the same manner as potassium.

### *Binary Compounds of Sodium.*

310. *Protoxide of Sodium*— $\text{NaO}$ ; eq.,  $(23.3 + 8 =) 31.3$ . This compound, usually called *soda*, is formed by the oxydation of sodium, as potassa is from potassium. With water it forms a solid hydrate, which is easily fusible, and very soluble both in water and alcohol. It is a powerful alkali, and very similar in all its properties to potassa. It is prepared from the carbonate in the same manner as the hydrate of potash.

Soda is easily distinguished from potash, the only substance for which it is likely to be mistaken, by a solution of tartaric acid, which forms with soda a very soluble salt, while that which this acid forms with potash is only partially soluble. With potash, therefore, a white precipitate will be formed, but not with soda.

311. *Chloride of Sodium*— $\text{NaCl}$ ; eq.,  $(23.3 + 35.4 =) 58.7$ .—This is the *common salt* of commerce. It may be formed by burning sodium in chlorine, but is obtained in

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310. What is soda? How may it be distinguished from potash?

311. What is chloride of sodium? Where is it obtained? What use is made of it?

great abundance as a solid deposition in various parts of the world, as in England, Poland, and at Abingdon, Virginia, and in the waters of brine springs, which abound in New York, Pennsylvania, Virginia, Kentucky, Ohio, and other states, as well as in other countries. Sea-water also contains it in the proportion of about 25 or 27 parts in every 1000 parts of the water.

The uses of this substance are well known. Besides the ordinary purposes to which it is applied, in preserving meat from putrefaction, and in seasoning food, it is used extensively in the arts, in glazing pottery-ware, in the manufacture of bleaching-salt, carbonate of soda, hydrochloric acid, &c.

### *Salts of Soda.*

312. *Carbonate of Soda*— $\text{NaO}, \text{CO}_2$ .—The carbonate of soda of commerce was formerly obtained by lixiviating the ashes of sea-weeds, in the same manner as the carbonate of potassa is obtained from the ashes of land-plants. But it is now manufactured altogether from common salt, which is first converted into sulphate of soda by sulphuric acid, and then the sulphate, mixed with charcoal and carbonate of lime, is heated intensely in a wind-furnace. The mass thus obtained is then digested in warm water, and the clear liquid drawn off, and evaporated to dryness; and the mass, mixed with charcoal or saw-dust, again heated in the furnace to complete the conversion of all the sulphate into carbonate of soda. By again digesting with water and evaporating, the pure carbonate is obtained. It is the *sal-soda* of commerce; and in a very impure state is known as *soda-ash*, or *British barilla*.

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312. From what is the carbonate of soda prepared? What use is made of it?

Carbonate of soda is extensively used in the manufacture of glass and hard soap, and for other purposes.

313. *Bicarbonate of Soda*— $\text{NaO}, \text{CO}_2 + \text{HO}, \text{CO}_2$ .—This salt is formed by exposing the carbonate to an atmosphere of carbonic acid, in the same manner as the bicarbonate of potash. Like the corresponding salt of potash, it always contains one atom of water, and is really a double carbonate of soda and water, as expressed in the above formula. It is often used by bakers as a substitute for sal-æterus.

314. *Sulphate of Soda*— $\text{Na}_2\text{O}, \text{SO}_3 + 10\text{HO}$ .—Sulphate of soda, or *Glauber's salt*, is sometimes found native in dry situations, but more frequently in solution in the waters of mineral springs. It is also obtained in the manufacture of hydrochloric acid (279). It was first made known by Glauber, from whom it received its name, although he himself called it *sal-mirabile*. It has a cooling, saline, and somewhat bitter taste; and is very soluble in water at a temperature  $91^\circ$  or  $92^\circ$ , but less so in water that is very cold or very hot. The crystals of this salt always contain more than half their weight of water of crystalization, which escapes when they are exposed to the open air, and they crumble into a white powder. Sulphate of soda is much used in medicine as a cathartic.

315. *Biborate of Soda*— $\text{NaO}, 2\text{BO}$ .—This salt occurs in solution in the waters of certain lakes in Thibet and the East Indies, from which it is obtained by evaporation, and imported into this country and England under the name of *tincal*. When refined, by solution and recrystallization, it is sold as *borax*, a substance well known for its extensive

313. What is bicarbonate of soda?

314. How is sulphate of soda prepared? By what other name is it known?

315. What is the common name for the biborate of soda? Where is it obtained?

use in the arts in various metallurgic operations. The crystals contain much water, which, however, is not given up even in the driest atmosphere, at ordinary temperatures; but when they are intensely heated, the water is first expelled, and then the salt fuses.

## LITHIUM.

*Symbol, L; Equivalent, 6.4; Density, —?*

316. *History, &c.*—Lithium is a very rare substance, and is found only in a few minerals, as spodumene, and the variety of mica called lepidolite. It is obtained from these in combination with oxygen as the protoxide, *lithia*. From this the metal may be procured with some difficulty by means of galvanism. It is a white metal, like sodium. The protoxide, *lithia*, is a powerful alkali, like potash or soda, but is less soluble. The name is from the Greek, *lithos*, a stone, in allusion to the source from which it is obtained.

AMMONIUM. (*Not Isolable.*)

*Symbol, NH<sub>4</sub>, or Am; Equivalent, 18.1; Density, —?*

317. *History, &c.*—This supposed compound has been heretofore alluded to (231), but is again introduced for the purpose of describing some compounds it forms with other bodies, which require a place here.

As before stated, ammonium has never been procured in a separate state; but it appears to exist in combination with

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316. From what is lithium obtained? In what is lithia found?

317. What is ammonium? Can it be obtained in a separate state?

other bodies, and to possess some of the characters of a metal. It can replace both potassium and sodium in their compounds, and is generally believed to be the basis of all the salts of ammonia.

### *Binary Compounds of Ammonium.*

318. *Protoxide of Ammonium*— $\text{NH}_4\text{O}$ , or  $\text{AmO}$ .—As is the case with ammonium, the existence of this compound is hypothetical. But all the ammonia salts of oxygen acids, it will be observed, contain an atom of water in their composition, which appears to be essential to their existence. This atom of water, combined with the ammonia ( $\text{NH}_3$ ), forms the compound in question, protoxide of ammonium ( $\text{NH}_4\text{O}$ ), which unites with the acid to form the salt. Thus, the composition of nitrate of ammonia, as formerly supposed, is  $\text{NH}_3, \text{NO}_5, \text{HO}$ , which evidently is the same as  $\text{NH}_4\text{O}, \text{NO}_5$ , except as to the mode of the arrangement of the particles.

319. *Chloride of Ammonium*— $\text{NH}_4\text{Cl}$ .—This is the compound often called *sal-ammoniac*, and hydrochlorate of ammonia. It may be obtained by neutralizing carbonate of ammonium by hydrochloric acid; but for use in the arts it is procured from the liquor obtained in the distillation of bones, in preparing animal charcoal, and also from that which condenses in the manufacture of coal-gas.

*Sal-ammoniac* is a white solid, very tough, and difficult to pulverize, and has a density of about 1.45. It has a pungent, saline taste, and is very soluble in water; and sublimes

318. What is the composition of protoxide of ammonium? Has it been obtained in a separate state? Of What may it be considered as composed?

319. What is the common name of chloride of ammonium? What are some of its properties?

without fusion at a temperature below redness. Triturated with recently-slaked lime, it yields ammonia, which is easily recognized by its pungent odor. It is used for various purposes in the arts and in medicine.

### *Salts of Ammonium.*

320. *Carbonates of Ammonia*.—There are several carbonates of ammonia. The one best known is the *sal-volatile* of the shops, which is a *sesquicarbonate*. It is a semi-transparent solid, which is very soluble in water, and has the pungent odor of ammonia. Its composition is  $2\text{NH}_4\text{O}, 3\text{CO}_2$ . Besides this there are the neutral carbonate and the bicarbonate, but they are seldom seen.

321. *Nitrate of Ammonia* ( $\text{NH}_3, \text{NO}_3 + \text{HO}$ ), or, as it is now considered, *nitrate of oxide of ammonium* ( $\text{NH}_4\text{O}, \text{NO}_3$ ), is prepared by neutralizing nitric acid with ammonia. It is a white salt, very soluble in water, and destitute of any ammoniacal odor. It is used in preparing nitrous oxide (225).

322. *Hydrosulphate of Sulphuret of Ammonium*— $\text{NH}_4\text{S}, \text{HS}$ .—This is the substance usually called *sulphuret of ammonia*, or *hydrosulphuret of ammonia*. It is formed by passing a current of sulphuretted hydrogen for some time through strong aqua ammoniæ, which should be kept cool by ice. It is much used by the chemist as a reagent.

It has been stated above (295) that most of the important salts are double oxides; but this, it will be noticed, is a double sulphuret,—sulphuret of hydrogen combined with sulphuret of ammonium. Other instances of the kind might be given; as the hydrosulphate of sulphuret of potassium, the composition of which is  $\text{KS}, \text{HS}$ .

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320. What is the common name for sesquicarbonate of ammonia?

321. What use is made of nitrate of ammonia?

322. What is the composition of *sulphuret of ammonia*? What is the name now given it?

## GROUP II.—METALLIC BASES OF THE ALKALINE EARTHS.

## BARIUM.

*Symbol, Ba; Equivalent, 68.6; Density, —?*

323. *History, &c.*—This metal is procured by passing vapor of potassium over baryta (oxide of barium) at a red heat. Its density is supposed to be about 2. Heated in the open air, it burns with a red flame, and is rapidly oxydized when thrown into water. Its name is from the Greek *barus*, heavy, its compounds generally possessing this characteristic property.

— *Binary Compounds of Barium.*

324. *Protoxide of Barium*— $\text{BaO}$ ; eq.,  $(68.6 + 8 =) 74.6$ . This compound has been known many years by the names of *barytes* and *baryta*. It may be obtained by decomposing nitrate of baryta by heat. It is a gray powder, which slakes like lime when water is poured upon it, and becomes very hot. It dissolves readily in water, but is less soluble than potash or soda; a property by which the alkaline earths are distinguished from the alkalies. It is very caustic to the taste, and affects vegetable colors in the same manner as the alkalies.

325. *Chloride of Barium*— $\text{BaCl}$ ; eq.,  $(68.6 + 35.4 =) 104$ .—This compound is formed by dissolving the native carbonate of baryta in diluted hydrochloric acid. It crystallizes in white scales, which contain two atoms of water.

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323. How is barium procured? What are its properties?

324. What is baryta? Describe it.

325. What is chloride of barium?



It is very soluble in water, and is much used as a test for sulphuric acid, with which baryta forms an insoluble sulphate.

*Salts of Baryta.*

326. *Carbonate of Baryta* ( $\text{BaO}, \text{CO}_2$ ) is found native, and called *witherite* by mineralogists. From it all the other salts of baryta may be prepared.

327. *Sulphate of Baryta*— $\text{BaO}, \text{SO}_3$ .—Sulphate of baryta is found abundantly in various places, often in beautiful crystals. It has a density of about 4.4, and is insoluble in water. When powdered and mixed with charcoal, and heated intensely, it is converted into sulphuret of barium, from which the other salts of baryta may be prepared, as from the native carbonate. By mineralogists, it is called *heavy spar*, because of its great weight. Ground to a fine powder, it is used as a substitute for white lead, either alone or mixed with white lead. All the soluble compounds of baryta are poisonous.

STRONTIUM.

*Symbol*, Sr; *Equivalent*, 43.8; *Density*, —?

328. *History, &c.*—Strontium is obtained from its oxide, strontia, in the same manner as barium; and in its appearance it is said very much to resemble that metal. Like barium, also, it decomposes water with the evolution of hydrogen, and oxydizes rapidly in the open air. It receives its name from Strontian, a village in Scotland, near which it was first obtained.

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326. What is carbonate of baryta? What use is made of the native carbonate?

327. What is sulphate of baryta called by mineralogists?

328. From what is strontium obtained?

*Binary Compounds of Strontium*

329. *Protoxide of Strontium*— $\text{SrO}$ .—This compound, which is the earth *strontia*, is formed by the oxydation of strontium. It is prepared also by heating the nitrate of strontia to redness, by which the acid is expelled. It much resembles baryta, seeming to sustain much the same relation to it that soda sustains to potash.

*Salts of Strontia.*

330. *Nitrate of Strontia* ( $\text{SrO}, \text{NO}_3$ ) is prepared by dissolving the native carbonate in diluted nitric acid. It is much employed in fire-works, to give a beautiful red color to the flame. To show this *red fire*, mix intimately 40 parts of this salt, 13 of sulphur, 5 of chlorate of potash, and 4 of sulphuret of antimony, and burn it upon a dry brick, or marble slab, in a dark room. All the compounds of strontia communicate a red tint to flame in which they are heated.

## CALCIUM.

*Symbol, Ca; Equivalent, 20.5; Density, —?*

331. *History, &c.*—Calcium is the metallic base of lime, from which it has been obtained, but only in very small quantity. It is said to be of a yellowish-white color, and rapidly oxydizes in the air. Little is known of its other properties.

329. What is the earth strontia composed of?

330. How is nitrate of strontia prepared? For what is it used?

331. What is calcium?

*Binary Compounds of Calcium.*

**332. Protoxide of Calcium.** *Lime*— $\text{CaO}$ ; eq.,  $20.5 + 8 = 28.5$ .—This compound, commonly known by the name of *lime* and *quicklime*, is obtained by exposing carbonate of lime to a strong red heat, so as to expel its carbonic acid. If lime of great purity is required, it should be prepared from pure carbonate of lime, such as Iceland spar or Carrara marble; but in burning lime in lime-kilns for making mortar, common limestone is employed.

Lime is a brittle, white, earthy solid, the specific gravity of which is about 2.3. It phosphoresces powerfully when heated to full redness, and hence its use in the Drummond light (217). It is one of the most infusible bodies known; fusing with difficulty even by the heat of the oxyhydrogen blowpipe.

Exposed to the air, it gradually absorbs carbonic acid and crumbles to powder. It has also a powerful affinity for water, which is absorbed instantly on being poured upon it; and the combination is attended with great increase of temperature, and formation of a white bulky hydrate. The process of *slaking* lime consists in forming this hydrate, and the hydrate itself is called *slaked* lime. It differs from the hydrates of strontia and baryta, in parting with its water at a red heat. Recently-slaked lime dissolves sparingly in water, and has this singular property, that it is more soluble in cold than in hot water. The solution has a caustic, acrid taste, and acts upon vegetable colors like the alkalies. Exposed to the air, it absorbs carbonic acid: and if agitated, becomes milky.

*Mortar*, for building, is prepared by mixing sand with

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332. From what is the purest lime procured? By what means? Describe it. Describe the process of slaking lime. Is lime soluble

recently-slaked lime. It becomes very hard by exposure to the air, in consequence of the absorption of carbonic acid by the lime. Combination seems also to take place, to some extent, between the silica of the sand and the lime. When the limestone from which the lime is made contains a considerable portion of silica, alumina, &c., it constitutes *hydraulic cement*, or *water-lime*. Mortar prepared from this has the property of becoming hard under water, which is not the case with that prepared from pure lime.

333. *Fluoride of Calcium* ( $\text{CaF}$ ) is the *fluor spar*, or *Derbyshire spar* of mineralogists. It is of use to the chemist as affording the chief source of the element fluorine.

### *Salts of Lime.*

334. *Carbonate of Lime*— $\text{CaO}, \text{CO}_2$ .—This is one of the most abundant mineral productions known; it is found in every country as *limestone*, *chalk*, *Iceland spar*, *marble*, &c. It is decomposed by heat, and furnishes the *quicklime* used in preparing mortar.

335. *Sulphate of Lime*— $\text{CaO}, \text{SO}_3 + 2\text{HO}$ .—This compound is well known as *gypsum* and *plaster of Paris*. Pure, crystalized specimens are sometimes called *selenite*, and compact varieties, *alabaster*. Common gypsum contains considerable water, which may be expelled by heat; but there is a variety destitute of water, called *anhydrite* by mineralogists. When powdered gypsum, the water of which

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in water? How is *mortar* for building prepared? What is *water-lime*, or *hydraulic cement*?

333. What is *fluoride of calcium* composed of?

334. What is said of the abundance of *carbonate of lime*? What are some of its varieties called? How is *quicklime* prepared from it?

335. By what names is *sulphate of lime* known? How is

has been expelled by a moderate heat, is again made into a paste with water, it soon becomes hard, or "sets," as the workmen say;—a property which adapts it admirably for many purposes in the arts. In stereotyping, a coat of this paste is spread carefully over type, set in the ordinary manner, which, soon becoming hard, is removed, and a cast in common type-metal taken from it. This, after certain preparations, and the emendation of any broken letters that may be found, constitutes a *stereotype plate*, used in printing.

Sulphate of lime is extensively used as a manure in many countries, with excellent effect. It is slightly soluble in water, and is often found in well and spring water, and gives it the property called hardness.

336. *Phosphates of Lime*.—There are several of these salts. One variety is found native, and is called *apatite*; it is an essential ingredient of all fertile soils. Phosphate of lime constitutes the chief part of the solid matter of the bones of animals.

337. *Hypochlorite of Lime*— $\text{CaO}, \text{ClO}$ .—This is the well-known *chloride of lime*, *bleaching-powder*, or *bleaching-salt* of commerce. It is formed by passing a current of chlorine through recently-slaked lime. It is a white powder, and emits a faint odor of chlorine. Great use is made of it in bleaching (273). For this purpose it is dissolved in water, and the articles to be bleached soaked in the solution, and then dipped in very dilute acid. The chlorine which is thus liberated produces the bleaching effect. The process is usually several times repeated.

it prepared for use in the arts? How is it used in stereotyping?

336. Is phosphate of lime very generally diffused?

337. What is hypochlorite of lime? What use is made of it?

## MAGNESIUM.

*Symbol, Mg; Equivalent, 12.7; Density, —?*

338. *History, &c.*—Magnesium is obtained from its chloride by passing vapor of sodium over it when heated to redness in a glass tube; chloride of sodium is formed and magnesium set free. It is a white metal, of considerable brilliancy, and quite malleable. Heated in the open air, it readily takes fire, and burns with a brilliant flame, producing the protoxide of the metal.

*Binary Compounds of Magnesium.*

339. *Protoxide of Magnesium.*—*Magnesia*— $\text{MgO}$ .—Magnesia is best obtained by heating the carbonate to redness, by which the carbonic acid is expelled. It is a soft, white powder, and is usually sold under the name of *calcined magnesia*. It is only very slightly soluble in water, requiring for this purpose 5000 or 6000 times its own weight of water. Hydrate of magnesia ( $\text{MgO}, \text{HO}$ ) is found native at Hoboken, New Jersey, and other places. Magnesia is very infusible, and communicates this property to minerals in which it predominates, as talc and soapstone.

*Salts of Magnesia.*

340. *Carbonate of Magnesia*— $\text{MgO}, \text{CO}_2$ .—Carbonate of magnesia is found native, in the *magnesite* of mineralogists,

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338. From what is magnesium obtained?

339. How is magnesia prepared from the carbonate?

340. Is carbonate of magnesia found native? What is its composition?

and may also be formed from the native sulphate. It is nearly insoluble in pure water, but dissolves in water impregnated with carbonic acid, forming the liquid magnesia of the shops.

341. *Sulphate of Magnesia* —  $\text{MgO}, \text{SO}_3 + 7\text{HO}$ .—This is the well-known *Epsom salt*, used in medicine. It is not unfrequently found in the waters of mineral springs, as at Epsom, in England, and may readily be formed by dissolving magnesia, or its carbonate, in sulphuric acid. It is very soluble in water, and has a bitter, saline, taste. It may readily be distinguished from sulphate of soda by the form of its crystals, or by pouring into a solution of it a little caustic potassa, which will cause a white precipitate. In sulphate of soda, no precipitate will be formed.

#### GROUP III.—METALLIC BASES OF THE EARTHS.

##### ALUMINUM.

*Symbol*, Al; *Equivalent*, 13.7; *Density*, —?

342. *History, &c.*—The metal aluminum is obtained by decomposing chloride of aluminum by the action of sodium, in the same manner as magnesium is prepared from its chloride. It is a gray powder, with a metallic lustre. Confined in a close crucible, it may be melted; but heated in the open air, it takes fire and burns with brilliancy.

##### *Binary Compounds of Aluminum.*

343. *Sesquioxide of Aluminum* —  $\text{Al}_2\text{O}_3$ .—This is the earth *alumina*, and is one of the most abundant of nature's

341. What is the common name of sulphate of magnesia? What use is made of it?

342. From what is the metal aluminum obtained?

productions. Like silica, it is found in every soil, and in almost all rocks upon the face of the earth. Crystallized, it forms the *ruby* and the *sapphire*, two of the most valuable gems. *Emery* also, so much used in the arts, is chiefly composed of this earth. It forms a large part of clay, and gives to it its tenacious character, fitting it for the use of the potter.

Pure alumina is a white powder, without taste or smell. It is easily prepared by pouring solution of caustic potash into a solution of alum, and washing and heating the soft mass that is precipitated. It contracts much in drying, and the dried mass adheres tenaciously to the tongue when applied to it.

### *Salts of Alumina.*

344. *Sulphate of Alumina and Potash*— $\text{Al}_2\text{O}_3, 3\text{SO}_3 + \text{KO}, \text{SO}_3 + 24 \text{HO}$ .—This double salt is the well-known *alum* of commerce. It is usually formed from a mineral substance called *alum-slate*, which is an argillaceous, slaty rock, containing iron pyrites. It is sometimes found naturally formed as an efflorescence upon the surface of the rock.

Alum is usually seen crystallized in octohedrons; it is very soluble in boiling water, and has a sweetish, astringent taste. When the crystals are heated, they melt and froth up very much, in consequence of the large quantity of water they contain. Alum is much used in medicine and in the arts, especially in dyeing and calico-printing.

Common or potash alum is the type of a whole family of alums; as *soda alum*, *ammonia alum*, *iron alum*, *chro-*

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343. What is the composition of alumina? What natural productions are composed of alumina? Describe this earth.

344. What is alum composed of? What are some of the different kinds of alum?



*mium alum*, &c. Soda and ammonia alums are produced by causing these substances to replace the potash in common alum; and iron and chromium alums, by replacing the alumina by the sesquioxides of iron and chromium. These alums are all exceedingly alike in their various properties, and all contain, when crystalized, 24 atoms of water.

345. *Silicates of Alumina*.—Several double silicates of alumina and other bases are found native, some of which are of great importance in the arts. *Feldspar* is a double silicate of alumina and potash, while *albite*, or *Clevelandite*, is a double silicate of alumina and soda. *Spodumene* and *petalite* are the same as the latter, except that they contain less soda, and a small portion of lithia.

Sometimes feldspar undergoes a natural decomposition, losing its potash and part of its silica, and is then called *kaolin*. This substance, which is essentially silicate of alumina, more or less pure, is the basis of all the varieties of *porcelain* or *China-ware*. The articles are made of this of the proper form, and when dry, are exposed to a high temperature in a furnace, by which they become very compact but do not fuse. They are then dipped in the glaze, which consists chiefly of feldspar, ground to a fine powder, and suspended in water, a coating of which adheres over the surface; and when the articles are dried and again subjected to the heat of the furnace, it fuses and forms a glassy envelope, which incorporates itself with the body previously formed, and increases its compactness and strength. The glaze also renders them impervious to liquids, and even to the gases. For the finer kinds of porcelain, the kaolin, which constitutes the body, is mixed with some substance, as alkali or lime, by which it is rendered partially fusible,

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345. What is said of the silicates of alumina? What is kaolin? Describe the mode of manufacturing *porcelain*, or *China-ware*.

and the glaze therefore becomes more perfectly incorporated with it, so as to render articles made of it slightly translucent. The colors are usually applied before the glaze, and are composed entirely of metallic oxides.

*Stone-ware* is made of an infusible clay; and when the articles are sufficiently heated in the furnace, common salt is thrown upon them, the soda of which combining with the materials of the clay forms a fusible compound that constitutes the glaze. Without this the articles would be porous, and water and other liquids would percolate through them.

*Red earthen-ware* is made of the most common kinds of clay, which contain lime and iron, and is so fusible that only a moderate heat is needed in baking articles made of it. The articles, after being shaped upon the potters' wheel, are thoroughly dried, and then coated over with litharge (oxide of lead) in fine powder, which, by the heat of the furnace afterwards applied, fuses and spreads over the surface so as to form a fine glaze. Such vessels however should never be used with acids, which would attack the oxide of lead and produce poisonous compounds.

*Bricks* are usually made of the same kind of clay as that just described. No glaze is required for them. The best bricks are now pressed when partially dry, to render them more solid, and to give them a smoother surface.

346. The following six metals are of rare occurrence. GLUCINUM is found in the mineral called *beryl*, and in the *emerald*;—ZIRCONIUM is contained in the *zircon* or *hyacinth*;—YTTRIUM in the mineral, *Gadolinite*;—THORIUM in *thorite* and *monasite*;—and CERIUM and LANTHANUM in the minerals *cerite* and *allanite*. Of the last two little is known with certainty.

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What is *stone-ware* made of? Of what is red earthen-ware made? How are bricks formed?

GROUP IV.—METALS WHICH, AT A RED HEAT, DECOMPOSE THE VAPOUR OF WATER, BUT ARE NOT ACTED UPON BY LIQUID WATER.

## MANGANESE.

*Symbol, Mn; Equivalent, 27.7; Density, 8.01.*

247. *History.*—Manganese was first obtained by Gahn, from the substance then called *magnesia nigra*, which has since been found to be an oxide of this metal. It received its present name to distinguish it from magnesium, which has already been described. It is never found in nature in its metallic state, but its compounds are very generally diffused, and traces of it occur in both animal and vegetable substances.

348. *Preparation.*—Metallic manganese, in consequence of its great affinity for oxygen, is not obtained without considerable difficulty. To procure it, the black oxide, in fine powder, is mixed into a paste with oil and lampblack, and exposed, in a close crucible, to the highest heat of a powerful furnace.

349. *Properties.*—Manganese is a hard, brittle metal, of a grayish-white color, and granular texture. It is exceedingly infusible, requiring the highest heat of a wind-furnace for fusion. It soon tarnishes on exposure to the air, and absorbs oxygen with rapidity when heated to redness in open vessels.

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347. Is manganese ever found native?

348. How may it be prepared?

349. Describe this metal.

*Binary Compounds of Manganese.*

350. Oxygen combines with manganese in no less than seven proportions, producing the compounds,  $\text{MnO}$ ,  $\text{Mn}_2\text{O}_3$ ,  $\text{MnO}_2$ ,  $\text{Mn}_3\text{O}_4$ ,  $\text{Mn}_4\text{O}_7$ ,  $\text{MnO}_3$ , and  $\text{Mn}_2\text{O}_7$ ; but only the peroxide, and the last two here mentioned, possess sufficient interest to require description here.

351. *Peroxide of Manganese*— $\text{MnO}_2$ .—This is the common, or *black oxide*, of this metal. It is found in considerable abundance in the state of Vermont, and in other places in this country. Heated either alone or with sulphuric acid, it gives up a part of its oxygen; but in the latter case, twice as much is obtained as in the former. Heated with hydrochloric acid (272), chloride of manganese is formed, and chlorine evolved. It is much employed in the arts, in the manufacture of glass, and bleaching-salt, and for other purposes. When crystalized, it is called by mineralogists *pyrolusite*. The sesquioxide very much resembles the peroxide in appearance, and is often fraudulently sold for it.

352. *Manganic Acid*— $\text{MnO}_3$ .—This compound has never been obtained in a separate state, but only in combination with bases. It is interesting as the first *metallic acid* we are called to consider in the progress of our course. It is formed, in combination with potash, by heating equal weights of peroxide of manganese and nitrate of potash to redness in an open crucible. The compound, *manganate of potash*, is of a dark-green color, and has long been known by the name of *chameleon mineral*. Dissolved in cold water, it

350. How many compounds of manganese and oxygen are there?

351. What use is made of the peroxide of manganese?

352. Has manganic acid been obtained in a separate state? On what account is it interesting? What is chameleon mineral?

forms a beautiful green solution, which by continued dilution changes to blue, purple, and, finally, to a brilliant red. Hence its name. The changes are much more rapid when hot water is used.

353. *Permanganic Acid*— $\text{Mn}_2\text{O}_7$ .—This acid, in combination with potash, is formed when solution of the manganate of potash is made with hot water, as above described, by the absorption of oxygen from the air. It is to the formation of this compound that the red color is owing which is finally obtained by solution of chameleon mineral.

From this red solution purple crystals of permanganate of potash may be obtained; but when an attempt is made to separate either this or the preceding acid from the bases with which they are united, they are decomposed.

354. *Chloride of Manganese* is formed by digesting the black oxide in hydrochloric acid. There are two known, the protochloride ( $\text{MnCl}$ ) and sesquichloride ( $\text{Mn}_2\text{Cl}_3$ ).

### *Salts of Manganese.*

There are several salts of manganese, but the only one of importance in the arts is the following:

355. *Sulphate of Manganese*— $\text{MnO}, \text{SO}_3 + 7\text{HO}$ .—This salt is formed by digesting the peroxide in strong sulphuric acid by the aid of heat, and filtering when it has become cold. The crystals of the salt are of a rose-red color, and are very soluble in water. It is used in dyeing.

353. How is permanganic acid produced in combination?

354. How is chloride of manganese formed?

355. How is sulphate of manganese formed?

## IRON.

*Symbol, Fe (Ferrum); Equivalent, 27.1; Density, 7.7.*

**356. History.**—Iron, the most abundant and most useful of all the metals, has been known from the remotest antiquity. The ores of the metal, as well as the metal itself, and some of its manufactures, are mentioned in the writings of Moses, and it is well known the ancient Greeks and Romans were acquainted with it.

Iron has been found native in Guilford County, North Carolina, and in Canaan, Connecticut, and also in Russia, but only in small quantities. The occurrence of iron of meteoric origin, associated with nickel and often with cobalt, is, however very common. Masses of this character, often of great magnitude, have been seen to fall from the high regions of the atmosphere, apparently in a state of vivid ignition or combustion. Their course is always much inclined to the horizon, and before striking the surface they often burst into fragments, which bury themselves deep in the soil. As no such compound has ever been found in proper iron-mines, it is believed that these bodies must have their origin in some region foreign to the earth.

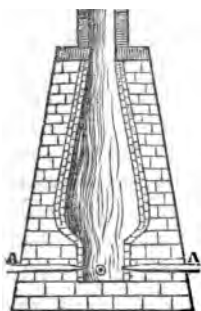
The most important ores of iron are the hydrated peroxide, called by mineralogists *brown hematite*; the peroxide (*specular iron*, or *red hematite*), and the black or magnetic oxide, which is a compound of the two preceding. The last is the natural magnet, or *loadstone*. English iron is obtained chiefly from the *clay-iron stone*, which is an impure carbonate of iron, found abundantly in connection with the

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356. What is said of the abundance and antiquity of iron? Is it found native? What is said of meteoric iron? With what is it combined? What are some of the most important ores of iron?

coal-measures; but in this country the metal is extracted almost entirely from the ores previously mentioned.

357. *Preparation.*—The preparation of perfectly-pure iron is a matter of considerable difficulty; but the ordinary method of reducing it from its ores, is, to heat them intensely, after having been reduced to powder, with charcoal or coke, and lime or siliceous sand, as the nature of the particular ore may require. The oxygen of the oxide of iron is absorbed by the heated carbon and carried off as carbonic acid, while the flux—for so the lime or sand is called when used for this purpose—unites with the earthy part of the ore and forms a fusible compound, that remains upon the surface, the melted iron, by its superior weight, falling to the bottom. When a sufficient quantity of melted iron has accumulated in the furnace, it is drawn off by an aperture at the bottom, which can be opened for the purpose. After the iron has been removed, the slag, formed by the union of the flux with the earthy matter of the ore, is also drawn off.



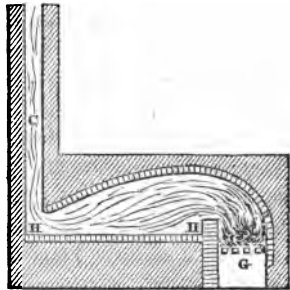
The accompanying figure represents a section of a *blast-furnace* which is used for the reduction of iron ores. It is usually built of stone, thirty or forty feet high, and lined inside with fire-brick. The charcoal, or coke, and the ore, in proper proportion, with the necessary flux, are thrown in at top; and A A are pipes leading from a powerful bellows, worked by water or steam power, for supplying the blast of air, which is generally forced through a series of pipes, placed above the furnace, so as to be kept heated by the

357. What is the ordinary method of reducing iron from its ores? What is the explanation of the process? Describe the blast-

blaze that constantly issues from the top. By this means it is heated before being forced into the ignited mass within the furnace. When once put in operation, such a furnace is kept in full blast for months, or even years, until repairs are needed; the fuel, with a proper proportion of ore and flux, being regularly supplied at the top.

The iron obtained by this process is the *cast* or *pig iron* of commerce, and contains a considerable quantity of carbon and other substances, by which it is rendered much more fusible than pure iron, but is at the same time harder and more brittle. To convert cast into *malleable iron*, it is exposed, in a melted state, to a current of air, which plays over its surface, or is forced through it. The process is usually conducted in a reverberatory furnace, a section of

which is shown in the figure in the margin. G is the grate upon which the fire is kindled, and H H the hearth which contains the melted metal. As the blaze from the fuel passes to the chimney, C, it comes in contact with the melted iron, and the carbon it contains—and perhaps other impurities—is gradually burnt out, and the iron becomes malleable. This process is called *puddling*.



But it is not absolutely essential that cast-iron should be fused in order to be changed into the malleable state. When small articles made of cast-iron are heated for a time in contact with powdered oxide of iron in close vessels,

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furnace used for reducing the ores of iron. What kind of iron is obtained by this process? How is malleable iron produced from cast-iron? Is it essential that cast-iron should be fused in order to be converted into malleable iron? How are small articles of cast-iron rendered malleable without melting them?



they are converted into malleable iron and still retain their form perfectly. The carbon, no doubt, is gradually extracted by the oxygen of the oxide of iron used.

358. *Steel* is formed by heating bars of malleable iron in close vessels in contact with charcoal, by which process a small quantity of carbon is absorbed and incorporated with the iron. This process is called *cementation*; and, although the proportion of carbon absorbed by the iron is small, yet very important changes are produced in its properties. It becomes more fusible, and may now be melted like cast-iron, and at the same time has become harder, and is capable of being *tempered*, that is, of being made hard or soft, at pleasure. Bars of steel, from the cementation process, always present a blistered surface, occasioned by the liberation of gaseous matter—probably carbonic oxide—within their substance; but when the metal has been melted and cast in moulds, it has a perfectly uniform texture, and is called *cast-steel*.

359. *Properties*.—We have already, under the last head, in part described the properties of iron. It is a hard metal, of a peculiar gray color, and strong metallic lustre, which is susceptible of being considerably heightened by polishing. Heated to redness, it becomes very soft and pliable, and is easily worked under the hammer, which gives it a decidedly fibrous structure. But its most remarkable property, to which its usefulness in the arts is very much owing, is its susceptibility of being *welded*;—that is, two pieces being brought together at a white heat and hammered, become perfectly united as one piece. It has a strong affinity for oxygen, and exposed to the air and moisture, it *rusts*, or oxydizes. Heated intensely in the blacksmith's forge, or in

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358. How is steel formed? What are some of the properties of steel? How is cast-steel formed?

359. What are some of the properties of iron? How may

the flame of the compound blowpipe, it burns with brilliancy. The same effect is produced by igniting a wire in a receiver of oxygen gas, or dropping iron-filings into the flame of a spirit-lamp. It has the property also of becoming magnetic under the influence of another magnet (160) or of the galvanic current (170). But pure iron loses its magnetism when the influence is removed. Some of the compounds of iron, especially steel and the black oxide, however, retain their magnetism permanently.

Iron is the most tenacious substance known; that is, it possesses the greatest strength. A wire of it  $\frac{1}{30}$ th of an inch in diameter has been known to sustain a weight of more than sixty pounds.

### *Binary Compounds of Iron.*

**360. Oxides of Iron.**—There are three oxides of iron, which have already been partially described. They are the protoxide ( $\text{FeO}$ ), sesquioxide ( $\text{Fe}_2\text{O}_3$ ), and the black oxide ( $\text{Fe}_3\text{O}_4$ ), which is considered as a compound of the other two ( $\text{FeO} + \text{Fe}_2\text{O}_3$ ). They are all found native, and may be formed by art. The red, or sesquioxide, is obtained by heating green vitriol (sulphate of the protoxide of iron) to redness in the open air, and is used as a polishing-powder, under the name of *rouge* or *colcothar*. Earth or clay highly impregnated with it forms the *red ochre* used by painters. The black oxide constitutes the scale that always forms upon the surface of iron when heated to redness in the open air. Large accumulations of it are often seen by the side of the smith's anvil.

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pieces of iron be welded? What is said of the strength of iron?

360. How many oxides of iron are there? How is *rouge* or *colcothar* formed?

361. *Sulphurets of Iron*.—There are several of these, but we shall mention only two, viz., the *protosulphuret* ( $\text{FeS}$ ) and the *bisulphuret* ( $\text{FeS}_2$ ). The former is of a dark color, and may be formed by heating a mixture of iron-filings and sulphur, or by heating an iron rod to whiteness and rubbing it with a roll of sulphur. It is used in preparing hydrosulphuric acid (254). The bisulphuret occurs native, and is called *iron pyrites*. It is of a beautiful yellow color, resembling gold, for which it has often been mistaken. It is usually crystalized in cubes. It is used in the manufacture of green vitriol and sulphuric acid, and sometimes for extracting its sulphur.

362. *Carburet of Iron*.—Both cast-iron and steel are considered as carburets of iron, but the ingredients do not seem to be united exactly in definite proportions. Cast-iron usually contains about 5 per cent. of carbon, but sometimes it contains as much as 10 per cent., while steel seldom contains as much as 2 per cent. *Graphite*, called also *plumbago*, and *black lead*, has been considered as a carburet of iron, but probably it is simply a particular form of carbon, usually containing a portion of iron as an accidental impurity. It is found abundantly in nature, and is used in the manufacture of pencils and crucibles, and as a polishing-powder for stoves and other articles made of iron.

*Protiodide of Iron* ( $\text{FeI}$ ) is formed by digesting iron-filings or wire in water containing iodine, and evaporating the solution obtained. It is used in medicine.

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361. How may sulphuret of iron be formed?

362. What are cast-iron and steel considered? What proportion of carbon is contained in cast-iron? What is graphite, or plumbago? How may iodide of iron be formed?

*Salts of Iron.*

363. *Carbonate of Iron* ( $\text{FeO}, \text{CO}_2$ ) occurs native, and is called *spathic iron*, or *steel ore*, by mineralogists. An impure variety is called *clay-iron stone* (356). It may also be obtained by adding solution of carbonate of soda to solution of green vitriol. Carbonate of iron, though insoluble in pure water, is dissolved by water charged with carbonic acid, and is thus contained in the water of *chalybeate springs*.

364. *Sulphate of Iron*— $\text{FeO}, \text{SO}_3 + 7\text{HO}$ .—This salt is the *green vitriol* or *copperas* of commerce, so extensively used in the arts. It is a sulphate of the protoxide, and is prepared on a large scale at Strafford, in Vermont, and other places, from iron pyrites, which is first roasted slightly, and then exposed in heaps to the atmosphere, from which oxygen is absorbed, converting the sulphur into sulphuric acid, and the iron into oxide of iron; the two together then uniting to form the salt in question. This salt is used in coloring black, and in the manufacture of writing-ink, and for other purposes.

The usual test for iron is solution of yellow prussiate of potash, which forms with it a beautiful blue. For an experiment, let a small quantity of the common hydrochloric acid be largely diluted with water, and then pour into it a few drops of solution of this prussiate, which will instantly give a fine sky-blue color if iron be present in the acid, as is almost certain to be the case. The iron is derived from the utensils made use of in the manufacture of the acid.

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363. Is carbonate of iron found native?

364. What is the common name for sulphate of iron? From what is it prepared on a large scale in Vermont? What test of iron is mentioned?

## ZINC.

*Symbol, Zn; Equivalent, 32.3; Density, 7.*

365. *History.*—This metal has been known several centuries, but was not, for many years, much used. Its chief ores are *calamine*, which is a native carbonate, and *blende*, which is a sulphuret; but several others are known. These ores are found in considerable abundance in New Jersey and other parts of this country.

366. *Preparation.*—The ores of zinc are reduced by first roasting them in the open air, and then distilling them with charcoal in close crucibles from which a tube descends directly through the bottom. The metal is volatilized by the heat, and descends through the tube, from which it is received into a vessel of water.

367. *Properties.*—Zinc has a bluish-white color and a strong metallic lustre. In masses, it always has a highly crystalline structure, and in commerce is called *spelter*. When cold it is quite brittle; but heated to about  $300^{\circ}$ , it becomes malleable, and may be rolled into thin sheets. Heated to  $773^{\circ}$ , it melts; at a little higher temperature, in the open air, it takes fire and burns with a brilliant white flame, producing the protoxide, which assumes an exceedingly delicate gossamer appearance, and has been called *philosophers' wool*, and by other names.

Zinc is now much used in the arts, in the preparation of brass, in the construction of galvanic batteries, and, rolled in thin sheets, as a substitute for sheet-iron and tin-plate.

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365. What are the chief ores of zinc?

366. How are its ores reduced?

367. What are some of the properties of zinc? What use is made of it in the arts?

*Binary Compounds of Zinc.*

368. *Protoxide of Zinc*— $\text{ZnO}$ .—This is the only oxide of zinc known, except perhaps a suboxide. It is of a yellowish-white color, and may be prepared, as above described, by heating zinc in the open air, or by precipitating it from solution of white vitriol (sulphate of zinc) by carbonate of ammonia. It has sometimes been used as a substitute for white lead in painting, and is said to answer the purpose very well.

369. *Chloride of Zinc*— $\text{ZnCl}$ .—Chloride of zinc is formed by dissolving commercial zinc in hydrochloric acid, or by burning zinc in chlorine gas. By evaporation it may be obtained as a white solid, but is very deliquescent in the air. Mixed with sal-ammoniac, it serves an excellent purpose in tinning articles of copper, brass, and other metals.

*Salts of Zinc.*

There are several salts of zinc, but the most important is the following:—

370. *Sulphate of Zinc*— $\text{ZnO}, \text{SO}_3 + 7\text{HO}$ .—Sulphate of zinc is a white salt, which, when crystalized, contains, like green vitriol, 7 atoms of water. In commerce, it is called *white vitriol*. It is very soluble in water; and is sometimes used in medicine as a powerful emetic.

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368. What is the only oxide of zinc known?

369. How is chloride of zinc formed?

370. What is the common name for sulphate of zinc?

## CADMIUM.

*Symbol, Cd; Equivalent, 55.8; Density, 8.6.*

371. *History, &c.*—Cadmium is a very volatile metal, usually found associated with zinc. It was discovered in 1817. In appearance it can scarcely be distinguished by the eye from tin, but is rather harder. It melts at  $442^{\circ}$ ,—the melting point of tin,—and sublimes at a temperature but little above the boiling point of mercury. Its properties indicate that it would be a useful metal in the arts, but it has hitherto been found only in very small quantities. Its compounds are unimportant.

## TIN.

*Symbol, Sn (Stannum); Equivalent, 58.9; Density, 7.3.*

372. *History.*—Tin has been known from the most remote antiquity, and was in common use in the time of Moses. It is supposed the ancients obtained it chiefly from Cornwall, England, the mines of which now yield a large part, it is said, of the tin of commerce. It is found also in India, Germany, Chili, and Mexico; but it is a little singular that it has not yet been discovered in the United States, except, perhaps, a few small crystals of the oxide in Chesterfield, Massachusetts, and a small vein of the same ore in the town of Jackson, in New Hampshire. The chief ores are the oxide and sulphuret.

371. Describe cadmium.

372. Has tin been long known? Is it found in the United States?

**373. Preparation and Properties.**—Most of the tin of commerce is obtained from the oxide, which is reduced by the action of charcoal at a high temperature. It is a brilliant white metal, like silver, but is rather softer. It is very malleable, and is rolled into very thin leaves, called *tin-foil*. It is inelastic, and when a rod of it is bent, a peculiar crackling noise is produced, occasioned by its crystalline structure. It melts at  $442^{\circ}$ , and at a red heat is rapidly oxydized; at a white heat it burns with flame.

Tin is used for many purposes in the arts, both alone and combined with other metals, as in *Britannia metal*, which is an alloy of tin and antimony, with a small proportion of copper. It is also used extensively to coat sheets of copper and iron, to prevent the oxydizing influence of the air and moisture, and other agents. Thin sheets of iron, coated over with tin, constitute the well-known and highly useful *tin-plate*.

### *Binary Compounds of Tin.*

**374.** There are three oxides of tin, the *protoxide* ( $\text{SnO}$ ), the *sesquioxide* ( $\text{Sn}_2\text{O}_3$ ), and the *peroxide* ( $\text{SnO}_2$ ); but the latter alone possesses sufficient importance to require a description.

**375. Peroxide of Tin** is formed by exposing the metal to the action of nitric acid a little diluted. It may also be precipitated from a solution of the perchloride of tin (soon to be described) by an alkali. As obtained by the mode last mentioned, it is soluble in acids, but not as procured by the other mode. It is of a yellowish-gray color, and from the

**373.** Describe the metal. What is Britannia metal? What is the tin-plate of commerce so well known?

**375.** How is peroxide of tin formed? For what purpose is it used?



circumstance that it is capable of combining with bases in the manner of an acid, it has been called *stannic acid*. It is much used as a polishing powder, under the name of *putty of tin*. Melted with ingredients for forming glass, it produces a white enamel.

376. *Perchloride of Tin*— $\text{SnCl}_2$ .—This compound is formed by distilling a mixture of 1 part of tin filings and 3 parts of corrosive sublimate, or by cautiously dissolving the metal in nitro-hydrochloric acid. It is much used as a mordant in dyeing, and as a disinfecting liquid. There is also a *protochloride*.

There are two *sulphurets* of tin;—the *persulphuret* ( $\text{SnS}_2$ ), sometimes called *aurum musivum*, has a yellow color, and metallic lustre, and is used as a paint, and also instead of the zinc amalgam (136) for exciting electrical machines.

There are no important salts of tin.

## COBALT.

*Symbol, Co; Equivalent, 29.5; Density, 8.5.*

377. *History, &c.*—Cobalt is almost always found associated with nickel, the metal next to be described;—as found in mines both are usually in combination with arsenic. The pure metal is obtained with difficulty; it is of a reddish white color, and is hard and brittle, and difficult to fuse. It is capable of becoming slightly magnetic.

376. How is perchloride of tin formed?

377. With what is cobalt usually found associated? What are some of the properties of cobalt?

*Binary and other Compounds of Cobalt.*

378. There are two oxides of cobalt, the *protoxide* ( $\text{CoO}$ ) and the *sesquioxide* ( $\text{Co}_2\text{O}_3$ ), the former of which, mixed with some impurities, is sold in commerce as a gray powder, under the name of *zaffre*. Fused with silica and potash, it forms *smalt*, which is used for coloring glass, porcelain, &c., blue. The *sesqui* or *peroxide* is unimportant.

379. *Chloride of Cobalt* ( $\text{CoCl}$ ) is formed by dissolving *zaffre* in hydrochloric acid. The solution has a pink color, and yields by evaporation small crystals of the same tint. Writing made with a diluted solution of it is nearly invisible, but becomes of a beautiful but pale blue color when the paper is warmed by the fire, and again disappears as the paper cools. It has been called *Hellot's Sympathetic Ink*. The addition of a salt of nickel gives the writing a green color.

The salts of cobalt possess no especial interest. The subcarbonate is a fine powder of a very delicate pink tint.

## NICKEL.

*Symbol, Ni; Equivalent, 29.6; Density, 8.5.*

380. *History, &c.*—Nickel and cobalt, as intimated above, are in nature almost inseparable companions. Arsenical nickel and cobalt are found at Chatham, in Connecticut, and also in Missouri, and in various places in Europe; but mines of these metals are not common. A beautiful hy-

378. What is *zaffre*? What use is made of it?

379. How is chloride of cobalt formed?

380. With what is nickel almost always combined? Describe this metal. What use is made of nickel?

drated, green, carbonate of nickel has recently been discovered in Lancaster County, Pennsylvania. Nickel is almost always combined with meteoric iron (356), of the mass of which it sometimes constitutes as much as ten per cent.

Pure nickel has a white color, and strong metallic lustre. It is quite hard but malleable, and is nearly as difficult to melt as iron. It is not readily acted upon by the air or by moisture. Of late it has been considerably used in the arts to form the alloy called *German silver*, which is said to be composed of copper 10 parts, zinc 6, and nickel 4

None of the compounds of nickel possess sufficient interest to require description here.

GROUP V.—METALS WHICH ARE INCAPABLE OF DECOMPOSING WATER, AND WHOSE OXIDES ARE NOT REDUCED BY THE MERE ACTION OF HEAT.

#### ARSENIC.

*Symbol, As; Equivalent, 75.3; Density, 5.88.*

381. *History and Preparation.*—Metallic arsenic sometimes occurs native, but usually it is found in combination with other metals, and especially with iron and cobalt. These and other arsenical ores are heated in such a manner as to condense the fumes of white oxide of arsenic that are sublimed; and the mass so obtained is then heated with charcoal, or black flux, in a close crucible, by which the oxide is reduced. The metal is expelled in the state of gas, and should be collected in a cool receiver, kept free as

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381. With what is arsenic usually found combined? What is the mode described for obtaining a little metallic arsenic from one of its ores?

possible from air. Let a common Hessian crucible be half filled with the mixture, and then place another crucible, a size smaller, in an inverted position above it, as shown in the figure, carefully luting them at their junction. A moderate heat should then be applied to the lower crucible and very gradually raised. The metallic arsenic will be sublimed from the mixture and condensed in small crystals in the inverted crucible, which should have a very small aperture in the bottom, to allow the air to escape as the heat is raised.



382. *Properties.*—Arsenic is a brittle metal, of a dark color, and feeble metallic lustre. Heated to about  $356^{\circ}$ , it is sublimed, without first melting, as is the case with most solids. Its vapor has a strong garlic odor, by which its presence may be recognized. The metal is sometimes sold under the name of *cobalt*, or *fly-powder*.

### *Binary Compounds of Arsenic.*

383. *Arsenious Acid*— $\text{AsO}_3$ .—This compound is the *arsenic*, or *rats' bane*, of commerce, well known as a destructive poison. It is always produced when metallic arsenic or its ores are heated in the open air. It is usually sold in a state of fine white powder; but when first sublimed, it is in the form of brittle masses, more or less transparent, colorless, of a vitreous lustre, and conchoidal fracture. This glass, which may also be obtained by fusion, gradually becomes opaque without undergoing any apparent change of constitution, but becomes more soluble in

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382. What are some of the properties of arsenic?

383. What is the common name for arsenious acid? How is it obtained?

water than before. Its specific gravity is 3.7. At  $380^{\circ}$  it is volatilized, yielding vapors which do not possess the odor of garlic, and which condense unchanged on cold surfaces.

This substance is so frequently used to destroy life that it becomes an important object to be able to detect it in cases where suspicions have been excited; but we reserve our remarks on this point until some others of the many compounds of arsenic have been described.

384. *Arsenic Acid*— $\text{AsO}_5$ .—This acid may be formed by dissolving arsenious acid, just described, in nitric acid mixed with a little of the hydrochloric, and evaporating to dryness. It is a powerful acid, much resembling phosphoric acid (260); with which it is isomorphous.

385. *Arseniuretted Hydrogen*— $\text{AsH}_3$ .—This gas is always evolved in the ordinary process for preparing hydrogen (218), when arsenic, or some of its compounds, is present, either free or in combination with the materials used. To prepare it, pour upon some pieces of zinc diluted sulphuric acid with a few drops of solution of arsenious acid; the gas, which burns with feeble blue flame, will be at once rapidly evolved. It has a slight garlic odor, and is exceedingly poisonous, destroying instantly small animals that are thrown into it.

386. *Sulphurets of Arsenic*.—The *bisulphuret of arsenic* ( $\text{As}_2$ ) is found native, and called *realgar* by mineralogists. It may also be formed by art. It is of a dull red color. The *persulphuret* ( $\text{AsS}_3$ ) is the *orpiment*, or *king's yellow* of commerce. It is formed by passing a current of sulphuretted hydrogen through a solution of arsenious acid, containing a little free muriatic acid. It is also found as a natural production, and is of a bright yellow color.

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384. What is arsenic acid?

385. How is arseniuretted hydrogen formed?

386. Describe the sulphurets of arsenic.

*Detection of Arsenic.*

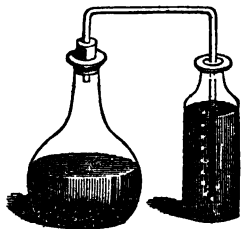
387. There are as many as ten or twelve different tests for arsenic, but we shall confine our remarks to four or five of the most important. A single test should never be relied on, but several different ones should always be applied to separate portions of the suspected substance.

1st. Pour into a portion of the suspected substance, if liquid, solution of ammonia-nitrate of silver, which will give the arsenious acid, if present, a yellow precipitate; but it should always be remembered that phosphoric acid, if present, would also give a similar precipitate, so that this test alone cannot be fully relied upon.

The ammonia-nitrate of silver is prepared by dropping aqua ammoniæ into solution of nitrate of silver, and stirring until the precipitate at first formed is *very nearly* all dissolved.

2d. Pour into another portion of the suspected liquid, ammonia-sulphate of copper, which gives with arsenious acid a beautiful green precipitate, called *Scheele's green*.

3d. Through another portion of the liquid, acidulated with muriatic acid, pass a current of sulphuretted hydrogen for half an hour, and then boil it a few moments; if arsenic be present, a yellow precipitate—orpiment (386)—will be formed. The mode of passing the current of gas through the liquid will be seen by the accompanying figure. The materials for producing the gas (254) are put into a flask, and a tube, bent twice at right angles, is inserted through a cork, so as to be air-tight; the other



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387. Describe some of the tests for arsenic. Should more than

end is then immersed in the liquid, contained in a glass vessel, so as to reach near the bottom, and the gas, as it escapes, bubbles through the liquid. The mode is the same as before described (254).

4th. Into still another portion of the liquid put a piece of bright metallic copper, and apply the heat of a spirit-lamp; if arsenious acid be present, the copper will soon be covered with a gray crust. This is called *Reinsch's* test.

5th. Mix a fifth portion of the suspected substance with a little dilute sulphuric acid, and pour it into a vial with some pieces of clean zinc, and insert a small tube of hard glass; if arsenic be present, arseniuretted hydrogen (385) will be evolved, which will issue in a jet from the tube. By inflaming this jet, and holding a piece of clean glass for a moment in the flame, a deposit of metallic arsenic will be found upon it, appearing as a dark gray spot. Antimony contained in the materials would give a result somewhat similar, but the two metals are easily distinguished. In using this delicate test, special care should be taken to have all the materials pure. This is called *Marsh's* test.



In cases of actual poisoning, it is not often that a pure solution is to be operated upon, as is supposed in the above examples, but the contents of the stomach which have been ejected, or the stomach itself, or some article of food. The proper method to be then pursued becomes more complicated; but the details will not be expected here. In judicial investigations, in addition to the above tests, it is usually required that sublimed metallic arsenic should be obtained. This is accomplished by taking a portion of the suspected substance, if in a solid state, or the precipitate

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one test be always used? In judicial investigations, what is usually required in addition to the above tests?

formed by the sulphuretted hydrogen process, and after drying it carefully, mixing it with black flux, and exposing it to the heat of a lamp, in a clean glass tube. The arsenic, if present, is sublimed, and forms a brilliant coating on the inside of the tube, just above the heated part.

388. *Antidote for Arsenic.*—In case of poisoning with so destructive a substance as arsenic, little can usually be expected from antidotes; but hydrated peroxide of iron is perhaps the best substance that can be administered. It may be formed by dissolving iron in aqua regia (280) and precipitating with ammonia. This compound forms with arsenious acid arsenite of iron, which is insoluble, and therefore inert.

## CHROMIUM.

*Symbol, Cr; Equivalent, 28.1; Density, 5.9.*

389. *History, &c.*—Chromium was discovered in 1797. It is found in considerable abundance in Massachusetts, Pennsylvania, and other states, in the mineral called *chrome iron*, and also in combination with oxide of lead. Its name comes from the Greek *chroma*, color, in allusion to the splendid color of many of its compounds. It is prepared by heating its oxides mixed with charcoal, but not without difficulty. The metal has a white color, and distinct metallic lustre. It is very brittle, infusible, and with difficulty attacked by the acids.

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388. What antidote of arsenic is mentioned?

389. In what mineral is chromium found? From what is the name derived?



*Binary Compounds of Chromium.*

390. *Oxides of Chromium.*—Oxygen forms several compounds with chromium; but two only, the *sesquioxide* ( $\text{Cr}_2\text{O}_3$ ) and *chromic acid* ( $\text{CrO}_3$ ) will claim attention here. The former is of a green color, and imparts a rich green to glass or porcelain, for which purpose it is highly valued. Chromic acid is prepared from the bichromate of potash; it is very soluble in water, and has a sour taste. With bases it forms important salts.

*Salts of Chromic Acid.*

391. *Chromate of Potash* ( $\text{KO},\text{CrO}_3$ ) is formed by heating a mixture of native chrome iron in powder with nitre, and digesting the mass obtained in water, and crystalizing. The crystals have a lemon-yellow color, and a bitter astringent taste. They are very soluble in water, but not in alcohol.

392. *Bichromate of Potash*— $\text{KO},2\text{CrO}_3$ .—This salt is formed by adding sulphuric acid to solution of the neutral chromate, and crystalizing. It is of a brilliant red color, and is used in dyeing.

393. *Chromate of Lead*— $\text{PbO},\text{CrO}_3$ .—This is the beautiful *chrome yellow*, used as a paint. It is formed by mixing solutions of chromate of potash and acetate of lead. *Chrome green* is formed by mixing the chromate of lead with Prussian blue, in a particular stage of the process of manufacture.

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390. What is chromic acid?

391. How is chromate of potash formed?

392. How is bichromate of potash formed? What is its color?

393. What is the common name of chromate of lead? What use is made of it?

## ANTIMONY.

*Symbol*, Sb (*Stibium*); *Equivalent*, 129.2; *Density*, 6.7.

394. *History*.—Antimony is remarkable as having been the first metal discovered after the seven metals (293) known to the ancients. It has been found in the metallic state, but is prepared chiefly from the sulphuret, which is not of unfrequent occurrence.

395. *Preparation*.—The metal, called also *regulus of antimony*, is obtained by heating the sulphuret with iron-filings, or black flux, in a close crucible.

396. *Properties*.—Antimony is a very brittle metal, of a white color, and brilliant lustre. It always has a highly crystalline structure, and melts at a temperature a little below redness. A small fragment, heated on a piece of charcoal before the blow-pipe, takes fire; and when thrown upon the floor breaks into numerous globules, which continue to burn as they are scattered, leaving a train to mark their path, and filling the air with fumes of the oxide. Alone it is too brittle for use, but in combination with other metals (373, 413) it forms very useful alloys.

*Binary Compounds of Antimony.*

397. Antimony forms with oxygen three compounds, two of which are acids; but they possess no special interest. There are also three chlorides, corresponding in composition with the oxides. The perchloride is formed by

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394. For what is antimony remarkable?

395. How is the metal reduced from its ores?

396. Describe this metal.

397. What is said of the compounds this metal forms with oxygen and chlorine?

dropping finely-powdered antimony into a vessel of chlorine gas, in which the metal takes fire spontaneously.

398. *Antimoniuretted Hydrogen* may be prepared in the same mode as the corresponding compound of arsenic (385).

The salts of antimony are unimportant.

#### BISMUTH.

*Symbol, Bi; Equivalent, 71; Density, 9.8.*

399. *History, &c.*—Metallic bismuth is found in small quantities in Monroe, Connecticut, and other places, but is chiefly obtained from the sulphuret. In mass, it much resembles antimony in its crystalline structure, but has less lustre, and is of a reddish color. It is brittle when cold, but may be hammered when moderately heated. It melts at about  $476^{\circ}$ , and sublimes at a high temperature. Bismuth is used in the arts in combination with other metals, but is too brittle for use by itself.

#### *Binary and other Compounds of Bismuth.*

There are several oxides, sulphurets, chlorides, &c.; but they possess no special importance.

400. *Nitrate of Bismuth*— $\text{BiO}_3\text{NO}_6$ .—This salt is formed by dissolving the metal in nitric acid. It is soluble in water; but if the solution is largely diluted, the salt is decomposed, and *subnitrate of bismuth* precipitated. This last salt is used in medicine, and also as a cosmetic.

398. How may antimoniuretted hydrogen be prepared?

399. Is bismuth found native? What are some of its properties?

400. How may nitrate of bismuth be formed?

## COPPER.

*Symbol*, Cu (*Cuprum*); *Equivalent*, 31.7; *Density*, 8.9.

401. *History*.—Copper has been known from the earliest ages, and is often found in the earth in its metallic state. A mass obtained in the region of Lake Superior, now in Washington, weighs some 3000 pounds. It is also found as a carbonate, sulphuret, and oxide, as well as in other combinations. The ores of copper are very generally diffused, some of them being found in almost every country.

402. *Preparation*.—Metallic copper is obtained from the oxides and the native carbonates simply by heating these ores with charcoal; but the sulphuret, especially when mixed with iron, is reduced with more difficulty.

403. *Properties*.—Copper is distinguished by its peculiar red color. It is very ductile and malleable, but less tenacious than iron. It is less liable to be corroded by air and moisture than iron, but is gradually corroded by the joint agency of these elements, and becomes coated with a green crust, which is carbonate of copper. Heated to redness, it becomes oxydized, and nitric acid readily dissolves it. It is used extensively in the arts, both alone and in combination with other metals.

404. *Alloys of Copper*.—Copper forms with other metals many very useful alloys. Three or four parts of copper with one of zinc constitutes *brass*; and by a variation of the proportions, the alloys called *tombac*, *Dutch gold*, and *pinchbeck*, are produced. *Bronze* is an alloy of copper and

401. Has copper been long known? Is it found native?

402. How is copper reduced from several of its ores which are mentioned?

403. By what peculiarity is copper distinguished? What is said of its corrosion by air and moisture?

404. Does copper form any useful alloys? What is brass?

about 10 per cent. of its weight of tin; and *bell-metal*, an alloy of 4 parts of copper with 1 of tin; while *speculum metal*, used for the mirrors of reflecting telescopes, contains about 2 parts of this metal to one of tin. Equal parts of copper and zinc form *hard solder*, which is used in soldering articles of brass.

### *Binary Compounds of Copper.*

405. *Oxides of Copper*.—*Red oxide* of copper ( $\text{Cu}_2\text{O}$ ) is a suboxide; it is found native. The black or protoxide ( $\text{CuO}$ ) is also found native, and is produced when copper is heated to redness in the open air. It is the base of the salts of copper.

There are two chlorides of copper, but only a single sulphuret ( $\text{Cu}_2\text{S}$ ), which is one of the common ores of the metal.

### *Salts of Copper.*

406. *Sulphate of Copper*— $\text{CuO}, \text{SO}_3 + 5\text{HO}$ .—This is the *blue vitriol* of commerce; and is formed by dissolving the protoxide in sulphuric acid. It is very soluble in water, and is extensively used in the arts. Its color is a fine blue.

407. *Nitrate of Copper* ( $\text{CuO}, \text{NO}_5 + 3\text{HO}$ ) is formed by dissolving copper in nitric acid. By slow evaporation, it may be obtained in crystals, which contain 3 atoms of water. It is deliquescent in the air, and very corrosive to the flesh.

408. *Carbonates of Copper*.—There are several car-

405. What oxides of copper are mentioned?

406. What is the blue vitriol of commerce?

407. How may nitrate of copper be formed?

408. What is said of the carbonates of copper?

bonates of copper, or rather subcarbonates, as the green and blue *malachites*, which are found native. *Green verditer*, or *mineral green*, is a hydrated subcarbonate, obtained by precipitating a solution of blue vitriol with carbonate of potash or soda.

Ammonia produces a deep blue color in diluted solutions of any of the salts of copper, by which they may always be distinguished.

409. *Arsenite of Copper*, or *Scheele's green*, is prepared by first dissolving arsenious acid and pearlash together in warm water, and then pouring into it gradually warm solution of sulphate of copper. It is of a beautiful green color, and is much used in painting. In commerce, it is called *Paris green*.

## LEAD.

*Symbol*, Pb (*Plumbum*); *Equivalent*, 103.7; *Density*, 11.38.

410. *History*.—Lead is one of the seven metals known to the ancients. Its most important and most abundant ore, from which all the lead of commerce is extracted, is the sulphuret, the *galena* of mineralogists; but it is found in many other forms, as carbonate, sulphate, phosphate, &c. It is very abundant in different parts of this country.

411. *Preparation*.—The metal is reduced from the sulphuret by first roasting it in the open air, and subsequently heating it with lime in a charcoal fire. The ore usually contains a little silver, which remains in combination with the lead.

409. How is arsenite of copper, or *Scheele's green*, formed?

410. What is the chief ore of lead?

411. How is the metal reduced from the sulphuret?

412. *Properties.*—Lead is a bluish-gray metal, and when recently cut has a strong metallic lustre; but the surface soon tarnishes on exposure to the air. It is soft and malleable, but not very tenacious. Heated to about  $612^{\circ}$ , it melts, but it cannot be volatilized by any degree of heat yet produced. Exposed to the air and moisture, it is gradually corroded; and a crust, the white carbonate, is formed upon its surface. .

The peculiar properties of lead fit it for use in the arts for a thousand purposes; but one of its most important uses is in constructing pipes for conveying water. But when the water is to be used for drinking, care should always be taken to have the tubes kept constantly filled with water, as the introduction of air (418) tends to form the highly poisonous carbonate; and even then the water should not be used until it has been proved by experiment that the particular water to be discharged by the tube is not capable of acting upon the lead.

Lead is gradually acted on by boiling sulphuric acid; but its only proper solvent among mineral acids is the nitric, which forms with it a soluble salt.

413. *Alloys of Lead.*—Lead forms with other metals many useful alloys. Two parts of tin and one of lead, fused together, form *soft solder*, which is much used in cementing together the different pieces of articles made of tin-plate (373), Britannia metal, &c. A coarser kind, which requires a higher temperature to melt it, is composed of lead 3 parts and tin only 1 part. *Pewter* is an alloy of lead and antimony, and sometimes a little copper. *Type-*

412. Describe some of the properties of lead. What is said to be one of the most important uses of lead? What danger attends its use for this purpose? What should always be done after putting down lead pipe before using the water conveyed by it?

413. What are some of the useful alloys of lead mentioned?

*metal* is an alloy of 3 parts of lead to one of antimony. Tin, lead, and bismuth, form a very fusible alloy; when made of 8 parts of bismuth, 5 of lead, and 3 of tin, it will melt in boiling water.

Lead shot is said to be made of an alloy of lead and metallic arsenic, the latter substance being added to facilitate the manufacture.

### *Binary Compounds of Lead.*

414. *Protoxide of Lead*— $\text{PbO}$ .—Protoxide of lead is formed by heating lead, in the open air, a little above its melting point; oxygen is gradually absorbed, and a yellow powder formed, which was formerly used as a paint, and called *massicot*. As usually manufactured, it is in the form of reddish-yellow scales, occasioned by its having been partially fused. It is much used in painting as a dryer, and is called *litharge*. It fuses readily at high temperatures, and enters into combination with several of the earths and alkalies, producing a transparent glass, which renders it an excellent substance for glazing some kinds of earthenware (345).

415. *Peroxide of Lead*— $\text{PbO}_2$ .—This oxide is obtained by digesting red lead (the compound next to be described) in nitric acid, which dissolves out the protoxide, leaving the peroxide quite pure, in the form of powder.

416. *Red Oxide of Lead*— $\text{Pb}_3\text{O}_4$ .—This compound is the *red lead*, or *minium*, of commerce, much used in the arts as a paint, and as one of the ingredients in the manufacture of flint glass (307). It is formed by heating metallic lead to a temperature of  $600^\circ$ , or  $700^\circ$ , in the open air, so

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414. What use is made of protoxide of lead? What is it called in commerce?

415. How is peroxide of lead formed?

416. What is red lead? What use is made of it?



as to oxydize it without fusing the oxide, and continuing the heat for some time. Heated to redness, it gives up a portion of its oxygen and is reduced to the protoxide.

417. *Sulphuret of Lead* ( $\text{PbS}$ ) is found in great abundance as a native production. It is also formed by passing a current of sulphuretted hydrogen through a solution of any salt of lead. As it occurs native, its color very much resembles that of metallic lead, but its structure is always crystalline.

### *Salts of Lead.*

418. *Carbonate of Lead*— $\text{PbO}, \text{CO}_2$ .—This is the *white lead* of commerce, so extensively used in painting. It is formed by several different modes, and is also found as a natural production. Nearly all the white lead of commerce, at the present time, is adulterated by mixing sulphate of baryta (327) with it in fine powder. Taken into the system, white lead acts as a violent poison.

419. *Sulphate of Lead*— $\text{PbO}, \text{SO}_3$ .—Sulphate of lead is found native, and called *anglesite* by mineralogists. It is also formed when solution of any sulphate, as sulphate of soda, is mixed with solution of any salt of lead. It is sometimes used in painting as a substitute for white lead.

420. Zinc precipitates lead from all its soluble salts in its metallic state. Make a solution of 1 part of nitrate or acetate of lead in 24 parts of distilled water, and suspend in it, near the top, a piece of clean zinc; the precipitation of the lead will immediately commence, and in the course of 24 or 48 hours, the metal will appear in the form of large thin leaves, called sometimes *arbor Saturni*.

417. Is sulphuret of lead found native?

418. What is white lead?

419. Is sulphate of lead found native?

420. How is the arbor Saturni formed?

421. The following metals, seven in number, being found only in very small quantities, and never having been applied to any useful purpose, may be passed over without further notice, viz:—MOLYBDENUM, VANADIUM, COLUMBIUM; TUNGSTEN, TELLURIUM, TITANIUM, and URANIUM. The oxide of titanium has been used in coloring mineral teeth.

GROUP VI.—METALS WHOSE OXIDES ARE REDUCED BY A RED HEAT.

MERCURY.

*Symbol*, Hg (*Hydrargyrum*); *Equiv.*, 202.8; *Density*, 13.5.

422. *History and Preparation.*—Mercury, or *quicksilver*, is one of the seven metals of the ancients. It is sometimes found in its metallic state; but most of the mercury of commerce is reduced from the native sulphuret, called *cinnabar*. It is not very generally diffused, there being but few mines that afford it in any considerable quantity. Most of the mercury used in this country comes from Spain; but it is obtained also in Germany, Siberia, in the East Indies, and in California. To extract the metal, the ore is heated with iron-filings or lime, by which means the metal is volatilized and the sulphur retained.

423. *Properties.*—Mercury is distinguished from all other metals by being fluid at ordinary temperatures. It is white as silver, and has a brilliant lustre. Cooled to  $-40^{\circ}$ , it freezes or becomes solid, and is then very malleable, and nearly the color of lead; at  $662^{\circ}$ , it boils and forms a colorless

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422. Was mercury known to the ancients? What is the ore from which most of the mercury of commerce is extracted?

423. How is mercury distinguished from all other metals? At what temperature does it become solid? What other properties are mentioned?

vapor. It readily dissolves several of the metals, as silver, gold, lead, and tin, and then becomes less fluid, and shows more disposition to tarnish by exposure to the air. Nitric acid, even when cold, acts upon it with energy; but none of the other acids without the aid of heat.

Mercury is used in the arts for many important purposes, and also in medicine and in the laboratory of the chemist.

424. *Amalgams*.—The alloys formed by the union of mercury with other metals are called *amalgams*. The metallic coating upon the backs of mirrors is an amalgam of tin.

### *Binary Compounds of Mercury.*

There are two oxides of mercury; but one only, the peroxide, will require to be here described.

425. *Peroxide of Mercury*— $\text{HgO}_2$ .—This is the *red precipitate* used in medicine. It is formed either by heating mercury nearly to its boiling point in a vessel to which the air has access, or by cautiously heating the nitrate so as to expel the nitric acid. It is usually seen in very small, shining, crystalline scales, which have a brick-red color. Heated to redness, it is decomposed, yielding mercury in the gaseous state, and oxygen.

426. *Protochloride of Mercury*— $\text{HgCl}$ .—This compound, familiarly known as *calomel*, is easily formed by precipitating a solution of the nitrate of the protoxide by common salt, or by subliming a mixture of the bichloride and metallic mercury. When heated, it is sublimed without change. It is usually seen as a white powder, with a slight yellowish tinge; and may always be known by instantly

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424. What are amalgams? What is the silvering upon the backs of mirrors composed of?

425. What is the composition of *red precipitate* used in medicine?

426. What is *calomel*?

turning black as ink, when touched with a drop of aqua ammoniæ, or solution of any caustic alkali.

427. *Bichloride of Mercury*— $\text{HgCl}_2$ .—Bichloride of mercury, or *corrosive sublimate*, is prepared by heating mercury in chlorine gas, or by subliming from a mixture of bisulphate of mercury and common salt. When obtained by the last-mode, it is a semi-transparent, colorless mass, of a crystalline structure. It is quite soluble in water and alcohol, and has an acrid, burning, nauseous taste. When heated, it first melts, and then sublimates at a temperature not above  $600^\circ$ . It is highly corrosive to the flesh, and taken internally, it is a most deadly poison. It is used in medicine, and in the process of *kyanizing* timber (from the name of the inventor of the process, Mr. Kyan) for use in ship-building, to prevent its rapid decay. The process consists merely in soaking the timber for a time in solution of this substance, which is believed to have this effect.

When the substance has been accidentally swallowed, the proper remedy is albumen, in the form of whites of eggs, with which corrosive sublimate forms an inert compound.

428. *Sulphurets of Mercury*.—There are two of these compounds, the protosulphuret ( $\text{HgS}$ ), which is black, and the bisulphuret ( $\text{HgS}_2$ ), or *cinnabar*, which is found native. It is also formed by art by several different modes, and constitutes the beautiful red paint called *vermillion*.

429. *Iodides of Mercury*.—There are two iodides of mercury, corresponding in composition with the oxides, sulphurets, &c. The biniodide ( $\text{HgI}_2$ ) is formed by mixing, in proper proportions, solutions of iodide of potassium and corrosive sublimate (189). The precipitate, which is of a

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427. What is the systematic name of *corrosive sublimate*? What are some of its properties? What use is made of it?

428. What is *vermillion*?

429. What is said of the iodides of mercury?

beautiful red, when dry may be sublimed and the vapor condensed in small yellow crystals, which, by being touched with the end of a wire, in a short time change again to red.

### *Salts of Mercury.*

430. *Nitrates of Mercury.*—Nitric acid acts readily upon mercury, forming the nitrate of the protoxide ( $\text{HgO}, \text{NO}_3$ ), if the acid has been considerably diluted, and no heat is applied; but strong acid, especially if aided by a slight heat, produces nitrate of the peroxide ( $\text{HgO}_2, \text{NO}_3$ ).

431. *Sulphates of Mercury.*—Sulphuric acid acts but slightly upon mercury when cold; but if heated, a sulphate of either the protoxide or peroxide is formed, according to the temperature. If 5 parts of sulphuric acid are boiled upon 4 parts of mercury, bisulphate of the peroxide ( $\text{HgO}_2, 2\text{SO}_3$ ) is formed; a compound which is used (427) in the manufacture of corrosive sublimate. Boiling water decomposes this sulphate, forming a yellow subsulphate, called *turpeth mineral*

### SILVER.

*Symbol, Ag (Argentum); Equivalent, 108.3; Density, 10.5.*

432. *History.*—This metal was known to the ancients. It frequently occurs native in silver mines, both massive and in octohedral or cubic crystals. It is also found in combination with gold, tellurium, antimony, copper, arsenic, and sulphur. In the state of sulphuret, it so frequently accompanies galena, the chief ore of lead, that the lead of commerce is rarely quite free from traces of silver.

430. How may nitrate of mercury be formed?

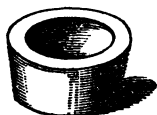
431. How is sulphate of mercury procured?

432. With what other substances is silver found combined?

Nearly all the silver obtained from the mines at the present time is found native, or is extracted from the sulphuret; but, according to Thompson, there are no less than seventeen species of silver ores.

**433. Preparation.**—When silver is contained in small particles disseminated through the ore, it is extracted by triturating the ore in fine powder with mercury, which dissolves the silver, and separates it at once from the mass as an amalgam. The amalgam being procured, it is subjected to pressure in leather bags, by which a portion of the mercury is separated, and the remainder is expelled by heat. Other ores of the metal, as the sulphuret, require to be treated differently. The chloride is easily reduced by the action of dilute sulphuric acid and pieces of zinc. The reduction is occasioned by the hydrogen that is liberated.

Silver is purified from small quantities of other metals present, except gold, by the process of *cupellation*. The silver, with several times its weight of lead, is placed upon a *cupel*; which is nothing more than a lump of bone-earth, an inch in diameter, and half that in height, with a small cavity in the upper surface; and exposed to a white heat, under a muffle, in a proper furnace. The metals are melted together, and the lead gradually oxydized and absorbed by the cupel, carrying with it any copper or other base metal that may be present, leaving the silver quite pure. This is the ordinary mode of testing the purity of silver coin and plate.



**434. Properties.**—Silver is a soft, white, metal, and is very malleable and ductile. It has a brilliant lustre, and is

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433. What is the method of reducing silver from its ore when the metal is disseminated in small grains through the ore? How may the chloride of silver be reduced? How is silver purified from small quantities of other metals except gold?

434. What are some of the properties of silver? What use is

susceptible of receiving a very fine polish. It is not acted upon by the atmosphere or by moisture, but is readily bleached by sulphur. It melts at about  $1873^{\circ}$ , Fahrenheit.

Silver is used in every country for many important purposes—for coin, and for manufacture into various articles of utility or ornament; but to render it more stiff and hard it is always alloyed with a portion of copper. The standard of purity for silver coin varies in different countries; but the coin of the United States contains 9 parts of pure silver and 1 part of copper;—that is, one-tenth part of the weight of the coin is copper. Thus, the dollar weighs 412.5 grains, of which 41.25 grains is alloy, and 371.25 pure silver. It is remarkable that the addition of a large proportion of copper scarcely produces any change in its brilliant white color.

Silver combines with other metals, forming alloys, which, however, possess no particular interest.

### *Binary Compounds of Silver.*

435. *Protoxide of Silver*— $\text{AgO}$ .—This seems to be the only well-determined oxide of silver, although two others are mentioned by writers on chemistry. It is thrown down as a dark-colored powder, when solution of caustic potash is poured into a solution of nitrate of silver. Heated to redness, it gives up all its oxygen, and pure silver is obtained.

436. *Chloride of Silver*— $\text{AgCl}$ .—This compound is occasionally found as a natural production, and called *horn silver*, and is easily formed artificially, by pouring solution

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made of it? What is the purity of the silver coin of the United States? What is the weight of the dollar of the United States?

435. How is protoxide of silver formed?

436. What is chloride of silver called when it occurs as a natural production?

of common salt into a solution of nitrate of silver. Formed by this mode, it is a beautifully white powder, which however soon becomes purple in diffused light, or black if exposed to the direct light of the sun, or if it is warmed before a fire. It is insoluble in water, but soluble in ammonia and hyposulphurous acid.

437. *Sulphuret of Silver* ( $\text{AgS}$ ) is formed by heating thin plates of silver in sulphur. It is also found as a natural production.

### *Salts of Silver.*

438. *Nitrate of Silver*— $\text{AgO}, \text{NO}_5$ .—This is the only salt of silver of any practical importance, and is well known by the name of *lunar caustic*. It is usually sold in small sticks, which are wrapped in paper, but may also be obtained in beautiful white, tabular crystals. The sticks usually contain a portion of nitre, which has been melted with it when cast in the moulds. Nitrate of silver is formed by dissolving silver in nitric acid diluted with twice its weight of distilled water. It is the basis of *indelible ink*, as it is called; but writing done with it may be removed by solution of cyanide of potassium. Nitrate of silver is very caustic to the flesh, and is used in medicine as a cautery. From its solution, metallic copper precipitates the silver as a fine powder; by mercury, the silver is thrown down in an arborescent form, which has been called the *arbor Dianæ*.

439. *Sulphate of Silver* ( $\text{AgO}, \text{SO}_3$ ) may be formed by boiling sulphuric acid upon metallic silver. It is a colorless salt, slightly soluble in boiling water.

437. How is sulphuret of silver formed?

438. What is the common name for nitrate of silver? How is it formed? Of what is it the basis? What is said of its action upon the flesh?

439. How may sulphate of silver be formed?



There are other salts of silver, but they possess no special importance.

## GOLD.

*Symbol*, Au (*Aurum*); *Equivalent*, 199.2; *Density*, 19.26.

440. *History*.—Gold appears to have been known to the earliest races of men, and to have been esteemed by them as much as by the moderns. It has hitherto been found only in the metallic state, either pure or in combination with other metals. It is sometimes found in primary mountains, but more frequently in alluvial depositions, especially among sand in the beds of rivers, having been washed by water out of disintegrated rocks in which it originally existed.

It occurs in almost every country, but most of it is obtained from the mines of South America, Hungary, and the Uralian mountains. It is also found in several of the United States, particularly in North Carolina, Virginia, and Georgia, and in the territory of California.

As gold exists in its ores in the metallic state, it is generally separated from them by the process of amalgamation, similar to that already described for obtaining silver, by which means it is separated from all other metals except silver. To remove this, so much silver must be added to it that the gold shall constitute but a fourth of the whole, and the mass boiled in nitric acid, which then readily acts upon it, dissolving out all the silver, and leaving the gold in a state of purity. This process has been called *quartation*, from the circumstance that the proportion of gold, in order that the nitric acid shall dissolve out all the silver, must not exceed a *quarter* of the whole mass. Other metals, except silver, may also be separated from it by cupellation (433).

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440. Has gold been long known? In what state only is it found? How is it separated from its ores? How may silver be removed from gold?

441. *Properties.*—Gold is readily distinguished from all other metals by its brilliant yellow color, and by its great malleability and ductility. It is capable of being beaten out into leaves so thin that light may be transmitted through them, which then appears of a greenish yellow color. It is not acted upon by air or moisture, though exposed to their influence for ages; nor is it oxydized by being kept in a state of fusion for any length of time. When intensely heated by the galvanic current, or by means of the compound blowpipe, it burns with a greenish blue flame, and is dissipated in the form of a purple powder, which is supposed to be an oxide. It is not acted upon by any single acid, but is dissolved in *aqua regia*, which is a mixture of one part of nitric and two parts of hydrochloric acids. It fuses at about 2016°.

Gold and silver, from the estimation in which they have been held, have been long known as the “precious metals;” and it is usual to estimate their purity in carats. A carat is to be understood as  $\frac{1}{24}$ th part of the mass; and a piece of gold or silver is 14, 18, or 20 carats fine, when so many 24ths of the whole are fine metal, the rest being alloy. But in the Mint of the United States, their fineness is estimated in thousandths: thus, gold or silver is said to be of the fineness 654, 789, 921, or 994, when so many thousandths of the whole mass consist of pure metal, the rest being alloy. The alloy of silver is always copper, but the alloy of gold may be either copper or silver, or a mixture of the two. Pure gold is so soft that some alloy is

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441. How is gold distinguished from other metals? Is it acted upon by air or moisture? May it be burned by means of the compound blowpipe? What acid only dissolves it? Why are gold and silver called “precious metals?” How is their fineness usually estimated? How is their fineness estimated at the United States’ Mint? What is the alloy in the silver and gold coins of this country? What is the object attained by adding this alloy? What

always needed to give it the proper stiffness, and to prevent too rapid wearing. In the gold coins of this country, one-tenth part is alloy, which is a mixture of silver and copper. The gold eagle of the United States weighs 258 grains, of which, of course, 25.8 grains are alloy.

Native gold is almost always alloyed with silver, but the proportion of this metal is very variable.

### *Binary Compounds of Gold.*

442. *Oxides of Gold.*—There are two, and perhaps three, oxides of gold; but the *teroxide* ( $\text{AuO}_3$ ) alone possesses any special importance. It is of a yellow color when first formed, but becomes black when all the water is expelled. It is used in coloring porcelain purple. In some cases it seems to act the part of a feeble acid, and has been called *auric acid*.

443. *Chlorides of Gold.*—There are two chlorides of gold; the *terchloride* ( $\text{AuCl}_3$ ), the one usually seen, is formed when gold is dissolved in aqua regia, showing that the chlorine liberated by the mixture of the acids is the real solvent. By *evaporating* the solution carefully, the chloride may be obtained as a solid, which is very soluble in water, alcohol, and ether. Solution of chloride of gold is very easily decomposed by green vitriol, and by organic substances. Protochloride of tin forms with it a beautiful purple powder, called *purple of Cassius*.

There are no well-determined salts of gold.

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is the proportion of alloy in the coins of this country? What is the weight of the gold eagle of the United States?

442. What oxides of gold are there? What use is made of the teroxide of gold?

443. How many chlorides of gold are there? How is purple of Cassius formed?

## PLATINUM.

*Symbol, Pt; Equivalent, 53.3; Density, 21.5.*

444. *History.*—Platinum was first recognized as a distinct metal in 1741, but was not described until 1749. It has hitherto been obtained chiefly from Brazil, Peru, and some other parts of South America, and from the Ural Mountains. It occurs only in the metallic state, associated with other metals, as gold, silver, lead, palladium, osmium, iridium, and rhodium.

445. *Properties.*—Platinum is a white metal, much resembling silver, but of inferior lustre. It is very malleable and ductile; but less so than either gold or silver. It is the heaviest substance known to man (except perhaps iridium), but is quite soft; and when heated, may be welded like iron (359), though not so easily. No single acid attacks it, but it is soluble in heated aqua regia. By heated nitre, or potassa or soda, it is oxydized. It cannot be melted by the most intense heat of the hottest furnace; but may be fused by the compound blowpipe, and the mass, on cooling, has a density of about 20. When a large surface of the metal is exposed to a mixture of oxygen and hydrogen, it has the singular property of causing them to combine, either silently or by an explosion. It acts in this way more readily when used in the spongy form (217), as precipitated from its solution by sal ammoniac.

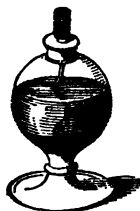
If a coil of platinum wire, recently ignited, be suspended in a deep glass, containing a little ether at the bottom, it

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444. When was platinum discovered? What other metals are usually associated with it?

445. Describe some of its properties. Is it attacked by any single acid? What is said of its fusibility? What is said of its action on a mixture of oxygen and hydrogen? Describe the experiment with the coil of platinum wire and a vessel of ether.

will instantly become incandescent, and glow with a red heat until the ether is entirely dissipated. The same effect may be produced by placing a coil of small platinum wire over the wick of a spirit-lamp, and after lighting it suddenly extinguishing the flame. The wire will continue at a red heat until all the alcohol is consumed. Such a lamp



(called a *flameless lamp*) is represented in the accompanying figure.

*Platinum black* is metallic platinum in a state of very fine division. It is prepared by passing a current of electricity through a solution of the metal in aqua regia, when it is deposited at the negative electrode. It acts powerfully upon many mixed gases, causing them to unite; and is used as a coating upon the silver plates of Smee's battery (150).

Platinum is of great importance in the laboratory, and is much used in the arts, especially for retorts for condensing (252) sulphuric acid. Its present value in the market is a little less than half that of gold.

### *Binary Compounds of Platinum.*

446. *Oxides of Platinum.*—Platinum forms with oxygen two compounds, the *protoxide* ( $\text{PtO}$ ) and the *peroxide* ( $\text{PtO}_2$ ).

447. *Chlorides of Platinum.*—The *protochloride* ( $\text{PtCl}$ ) is formed by heating the bichloride so as to expel one half of its chlorine; and the *bichloride* ( $\text{PtCl}_2$ ) is always the

Describe the flameless lamp. What is platinum black? What use is made of this metal? How does its value compare with that of gold?

446. How many oxides of platinum are there?

447. How is the bichloride of platinum formed?

product of the solution of the metal in aqua regia. By carefully evaporating this solution, the bichloride is obtained in the solid form. Like the terchloride of gold, it is a very deliquescent substance, and is soluble in alcohol and ether.

PALLADIUM, RHODIUM, OSMIUM, IRIDIUM.

These four rare metals are usually found associated with platinum.

448. PALLADIUM (*Symbol*, Pd; *Equivalent*, 53.3) is a grayish-white metal, very malleable and infusible. Its density is about 11.3; and all its properties are such as to render it very useful in the arts, if it could be obtained in sufficient quantity.

449. RHODIUM (*Symbol*, R; *Equivalent*, 52.2) is a reddish-white metal, very hard and infusible. Its density is about 11.

450. OSMIUM (*Symbol*, Os; *Equivalent*, 99.7) is a white, brittle metal, obtained with difficulty in a coherent state. It is distinguished for taking fire readily when heated in the form of powder, and forming a volatile poisonous oxide.

451. IRIDIUM (*Symbol*, Ir; *Equivalent*, 98.8) is a pale, white metal, and is even less fusible than platinum. It is slightly ductile, and very hard. A native alloy of this metal and rhodium is used for forming the tips of gold pens. Some recent experiments indicate that iridium is a little heavier than platinum; and if this be so, it is entitled to the distinction of being considered the heaviest body known.

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What four metals are mentioned as being found associated with platinum?

451. Describe iridium. What use is made of the native alloy of rhodium and iridium? What is said of the density of iridium?

## PART IV.

### ORGANIC CHEMISTRY.

#### GENERAL PROPERTIES OF ORGANIC BODIES.

452. ORGANIC bodies are those which are produced by the union of the elementary substances by means of the organs of plants and animals, and of course under the influence of the principle of life. They are therefore always compound, and differ essentially in many respects from inorganic bodies.—1. Their leading elements are oxygen, hydrogen, carbon, and nitrogen, in different proportions, and differently united. With these are also occasionally combined phosphorus, sulphur, lime and iron. 2. An atom, or equivalent, usually contains a greater number of simple atoms than is found in inorganic bodies. Thus, a single atom of albumen contains no less than 883 simple atoms (or, according to one author, 1765 atoms); and an atom of spermaceti, 431 simple atoms;—numbers to which we find no approximation in any inorganic compounds. 3. As a necessary consequence of the fact that the essential elements of organic bodies are few, the numerous varieties which we have are produced entirely by differences in the proportions of the ingredients, or differences in the mode

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452. What are organic bodies? Are they always compound? What are the leading elements of organic bodies? What other substances are occasionally present? What is said of the atoms or equivalents of organic bodies? What illustration is given? How are the numerous varieties of organic bodies produced?

of their grouping. Thus, sugar, starch, and woody fibre, contain precisely the same elements, but there is a slight difference in the proportions; while cyanate of ammonia, and the substance called urea, contain the same elements in the same proportion, but differently grouped. 4. Most organic bodies, when life is extinct, tend rapidly to decompose spontaneously. These compounds are formed by the influence of the living principle controlling the natural affinities of the elements; but when this principle has ceased to operate, and the natural affinities are uncontrolled, these elements show a disposition to rearrange themselves in a different order. 5. Organic bodies, as a general thing, cannot be imitated by art. We know their ingredients, and the proportions in which they are united; but we cannot cause the ingredients to combine so as to produce the compound. In a few instances, organic substances have been produced by artificial means, as in the case of urea. 6. Organic substances are invariably decomposed by a red heat; and even a much lower temperature often occasions essential changes in them.

453. The elements of organic bodies are united according to the laws of definite proportion, just as in inorganic chemistry; and the same nomenclature applies to some extent, but not universally. The acids, for instance, obtained from organic substances, usually receive their names

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What illustration of this point is given? What changes do most organic bodies undergo after death? How are organic compounds formed? Why should a rearrangement of the particles be expected to take place when the principle of life has become extinct? Can organic substances, as a general thing, be imitated by art? Are there a few exceptions? How are organic bodies affected by a red heat?

453. Are the elements of organic bodies united according to the laws of combination? Does the nomenclature apply to them in full? How are the acids of organic bodies named? Can you give an instance?



from the natural productions in which they are chiefly formed; and the same may also be said of the vegetable alkalies, and other substances. Thus, citric and malic acids are so called, because obtained from the lemon (*citron*) and the apple (*malum*) respectively. So also the vegetable alkali, cinchonia, is obtained from the bark of the *cinchona condaminea*; veratria, from the *veratrum album*, &c.

454. It is exceedingly difficult to fix upon any very satisfactory classification of the substances treated of in this department of chemistry, owing very probably to the limited state of our knowledge. There is indeed a very well defined class of acids, consisting of a number of families, and also a less definite class of alkalies; there is likewise a class, including starch and sugar, that may be called intermediate or neutral principles, and another of oils; but several of these classes are so related to each other, that we can scarcely satisfy ourselves where to fix the dividing line between any two of them. Many substances possess such a peculiar combination of properties, that they seem to belong about as well to one class as to another. The classification adopted in the following pages seems to bring together substances naturally allied as well as any other, and is therefore well adapted to the purposes of an elementary course of instruction.

455. *Compound Radicals*.—Organic bodies, we have seen (452), are necessarily compound; though many of them are capable of performing the functions of elements, or simple substances, and are therefore properly called compound radicals. They are often capable of combining with the metals, or other elements; or may be substituted in compounds for the simple elements. Thus, cyanogen

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454. What is said of the difficulty of classifying organic substances?

455. What are compound radicals? What one is mentioned?

(247) ( $C_2N$ ), though a compound body, combines with the metals like oxygen, chlorine, sulphur, &c., forming cyanides; united with oxygen, it forms cyanic acid; and with hydrogen, it forms hydrocyanic or prussic acid, &c. Some few of these radicals have been obtained in a separate state, as cyanogen and aldehyde; but others can be obtained only in combination. This is the case with the radical, benzyle ( $C_{14}H_5O_2$ ). The composition of oil of bitter almonds is  $C_{14}H_5O_2$ ; but if we pass a current of chlorine through it, we obtain the compound  $C_{14}H_5O_2Cl$ , which is evidently equivalent to  $C_{14}H_5O_2-H + Cl$ ; that is, an atom of hydrogen in the oil has simply been replaced by an atom of chlorine. By other modes of treatment we get the compounds  $C_{14}H_5O_2I$ , and  $C_{14}H_5O_2S$ , in both of which the same combination of elements ( $C_{14}H_5O_2$ ) is seen, combined in the one case with an atom of iodine, and in the other with an atom of sulphur. This combination of elements ( $C_{14}H_5O_2$ ) is called benzyle\* (from *benzoin*, a kind of resin, and *ule*, principle); and if we adopt Bz as its symbol, we may express the above compounds thus, BzH, BzI, BzS. They are therefore the hyduret, iodide, and sulphuret of benzyle.

There are many others of these radicals; but it will come within the scope of this work to treat of only a few of them, which will be described in their proper places.

456. *Chemical Types*.—In many organic substances, one of the ingredients may often be displaced, and an equal number of equivalents of another substituted in its place, without an entire change of properties. Thus, acetic acid ( $C_4H_4O_2$ ), when treated with chlorine, loses 3 equivalents of hydrogen and gains 3 equivalents of chlorine, forming

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\* Sometimes written benzule.

Have some of these been obtained in a separate state? Are there others that have not been so obtained?

456. May one or more of the ingredients of a compound often

chloroacetic acid ( $C_2HCl_3O_2$ ), a substance which closely resembles the common acetic acid; and alcohol ( $C_2H_5O_2$ ) may have all its oxygen replaced by sulphur, forming sulphur-alcohol, the composition of which will of course be  $C_2H_5S_2$ . Such instances might easily be multiplied; they occur in inorganic as well as in organic chemistry, as in the case of the alums (344). In some cases, one substitution after another may be made, until nearly all the original ingredients are removed, and their place supplied by others, the general character of the compound all the time remaining essentially the same. All the several compounds so formed, in any particular case, are said to belong to the same *type*.

#### STARCH, SUGAR, GUM, LIGNINE.

457. These four organic bodies constitute a natural family, possessing this remarkable peculiarity, that each member is composed of twelve atoms of carbon, united with a certain number of atoms of water, or rather with the elements of water, oxygen and hydrogen. In general, they are nutritious substances, and do not possess any very active chemical affinities.

#### STARCH ( $C_{12}H_{10}O_{10}$ ).

458. Starch, or fecula, is obtained from a variety of vegetable substances, as the different grains; and from many roots, as the potato; and also sometimes from the stems of plants. It is contained in the cavities of vegetable tissues,

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be replaced by another without entirely changing the properties of the compound?

457. What is said of the composition of starch, sugar, gum, and lignine?

458. From what is starch obtained? What is said of the grains

in the form of small white grains, which have a rounded outline; and each grain is inclosed in a delicate envelope, that is not acted upon by cold water, but is ruptured by the expansion of the inclosed substance, when the water is heated nearly to the boiling point. These grains vary in size in the starch obtained from different substances; those of the potato being about  $\frac{1}{200}$ th of an inch in diameter, while those from wheat do not exceed  $\frac{1}{500}$ th of an inch. Potatoes afford the purest starch, which is obtained by mashing the tuber, and washing the pulp with cold water, upon a fine sieve, or inclosed in a linen bag. The grains of starch are carried through by the water, which, by standing, gradually deposits them as a sediment at the bottom. It may be procured from wheat and the other grains in a similar manner. There are several varieties of starch, as *arrow-root*, *sago*, and *cassava* or *tapioca*; all of which are well known.

Starch is an insipid, inodorous white solid, quite insoluble in cold water, alcohol, or ether, but is dissolved by hot water, forming a transparent solution. As usually prepared, it is a thick tenacious jelly. When kept for some time at a temperature between  $300^{\circ}$  and  $400^{\circ}$ , starch undergoes a peculiar change, and is then very soluble in cold water, and is called *British gum*, or *leiocome*.

459. Iodine answers well as a test for starch, with which it forms a beautiful blue compound that is insoluble in water. The arrangement of the starch-grains in the potato may be shown by making a very thin slice of a tuber, and dipping it in a dilute solution of iodine in alcohol, and then inspecting it by the compound microscope. To the naked

of starch? How may the starch be separated from potatoes? What are some of the different varieties of starch? What are some of its properties? What is British gum?

459. What test of starch is mentioned?

eye, the slice will appear of a uniform purple ; but under the microscope, it will be seen that only the starch-grains are colored, which are regularly arranged in the vegetable tissue.

460. *Dextrine* is a substance formed by gently heating starch in water acidulated with sulphuric acid, or containing infusion of malt. It has the same composition as starch, but is very soluble in cold water, and is not colored by iodine. If the mixture is boiled for some time, grape-sugar is formed, of which more will be said hereafter.

461. *Diastase*. This is a substance produced in small quantity in the process of malting grain, and is found in the potato soon after germination commences, in the parts near the young germs. It is noted for its specific action upon starch, converting it first into dextrine, in the same manner (466) as diluted sulphuric acid, and afterwards into grape-sugar. Diastase is known to contain nitrogen, but its composition has not been well determined.

462. The operation of malting consists in exposing grain (usually barley) to the proper degree of heat and moisture, with the free accession of atmospheric air to produce incipient germination, and then suddenly checking it by elevating the temperature. This is done by first soaking the grain in water until it is fully swelled, and then placing it in heaps upon a floor until it begins to germinate, when the further progress of the vegetative process is arrested by quickly drying it at a moderately-elevated temperature. During the incipient germination, a portion of diastase is produced, by which, in the subsequent processes to which the grain is subjected, much of the starch of the grain is

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460. What is dextrine ?

461. What is diastase ? What is said of its action upon starch ?

462. In what does the operation of malting grain consist ? How is it performed ?

converted into dextrine, or grape-sugar; and the grain (now called *malt*) becomes fitted for the uses to which it is applied. It is chiefly used in the manufacture of beer.

## SUGARS.

463. There are several varieties of sugar; but the most common are cane-sugar and grape-sugar,—names suggested by the substances from which they are usually derived. They possess a sweet taste, are very soluble in water, and are susceptible of undergoing a peculiar change, to be described hereafter, called the vinous fermentation, by which alcohol is produced.

464. *Cane-sugar* —  $C_{12}H_{22}O_{11}$ .—Cane-sugar is obtained chiefly from the juice of the sugar-cane (*arundo saccharifera*), but is procured also in this country in large quantities from the sap of the sugar-maple (*acer saccharinum*). Many plants contain it in their juices, as the common beet and other roots, and the stalks of Indian corn. Their juices are evaporated until a dense syrup is obtained, from which a large portion of the sugar crystallizes on cooling; and the remaining liquid portion is then drained off, and constitutes *treacle*, or *molasses*. During the boiling, a little lime-water is usually added, to neutralize any free acid that may be present. It may be further refined by dissolving and boiling with albumen, or by filtering through animal charcoal. This constitutes loaf and other kinds of refined sugars.

465. Pure sugar is a white, inodorous substance, of a very agreeable sweet taste, which it imparts to its solutions. By slow evaporation, in a very warm room, it is obtained

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463. What two varieties of sugar are mentioned? What are some of the properties of sugar?

464. From what is cane-sugar obtained? What is its composition?

465. What are some of the properties of sugar? What is rock-

in large crystals, which are sold as *rock-candy*. It is very soluble in water, but is dissolved only in small quantity in alcohol. Its density is 1.56. Heated to nearly  $400^{\circ}$ , it melts and forms a transparent mass on cooling, called *barley-sugar*, which however, after a time, becomes white and opaque, and is then found to be a mass of small crystals. If still more heated, it gives up two atoms of water, and a brown substance is formed called *caramel*, which has the composition  $C_{12}H_2O_9$ , the effect of the heat having been to expel from the sugar two atoms of water, or its elements. This formerly led chemists erroneously to consider  $C_{12}H_2O_9$  as the real composition of sugar; but it is now universally believed to be (as stated above)  $C_{12}H_{11}O_{11}$ .

When sugar is digested with the alkalis, and some of the alkaline earths and metallic oxides, it is decomposed into a substance having the same composition as caramel and water, the former substance entering into combination with the base, whichever it may be that is used.

466. *Grape-Sugar* —  $C_{12}H_{14}O_{14}$ , or  $C_{12}H_{12}O_{12} + 2HO$ . — This substance, which much resembles the preceding, has for its composition, when crystalized,  $C_{12}H_{14}O_{14}$ ; but by a boiling heat, two equivalents of water are expelled. It is more generally diffused in nature than cane-sugar, being found in the grape and most other sweet fruits. It constitutes also the solid part of honey. It may be obtained from grapes by expressing the juice, and neutralizing the free acid with chalk, and then clarifying and crystalizing in the same manner as with cane-sugar.

It may also be prepared from several substances, which have nearly the same composition, as starch, gum, and woody fibre or lignine; and is occasionally produced in

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candy? What is barley-sugar? What is caramel? How is sugar affected by digestion with the alkalis?

466. What is the composition of grape-sugar? From what may

the animal system, in certain forms of disease, as *diabetes*, and is then found in the urine. Grape-sugar is not so easy to crystalize as the preceding variety, nor is it as soluble in water. Its specific gravity is 1.38. It is sometimes called *starch-sugar*, *diabetic sugar*, and *glucose*.

To prepare this sugar from starch, 50 parts of starch, 200 parts of water, and 1 part of sulphuric acid, are boiled together for 36 or 40 hours, care being taken occasionally to replace the water that escapes by evaporation. The acid is then removed by powdered chalk, and the clear liquid evaporated to the consistence of syrup, from which the sugar crystalizes on cooling. The same effect is produced by an infusion of malt (462).

Woody fibre also yields grape-sugar by boiling with sulphuric acid. Twelve parts of fine saw-dust, or of paper, or linen rags, are moistened with 5 parts of acid previously diluted with 1 part of water, and allowed to cool. After standing 24 hours, it is mixed with a large quantity of water, and boiled 10 or 12 hours, and the acid is then removed by chalk, as before; and the sugar obtained by evaporation and crystalization.

The action of the acid, in both of these cases, has simply been to cause the absorption of water, or rather the elements of water, by the substances used. Thus, starch,  $C_{12}H_{10}O_{10} + 4HO = C_{12}H_{14}O_{14}$ , sugar. So woody fibre,  $C_{12}H_8O_8 + 6HO = C_{12}H_{14}O_{14}$ , sugar, as before.

467. *Sugar of Milk* ( $C_{24}H_{24}O_{24}$ , or  $C_{24}H_{18}O_{19} + 5HO$ ) is obtained by evaporating the whey of milk, and purifying with animal charcoal, and crystalizing. It is less soluble

it be obtained? Is it sometimes found in the animal system? How may it be prepared from starch, woody-fibre, and other substances that have a similar composition? What appears to be the action of the acid in this process?

467. How is sugar of milk obtained?



in water than either of the other varieties, and less sweet to the taste. It is also called *lactine*.

Other varieties of sugar are *mushroom-sugar*, *liquorice-sugar*, and *manna-sugar*, or *mannite*; but they possess little importance.



468. This name is generally applied to those vegetable substances which are more or less soluble in water, but are insoluble in alcohol. The properties of gum are best studied in pure specimens of gum-arabic, of which it is the principal ingredient. It is colorless, transparent, inodorous, and insipid; and when dry, it is very brittle, and has a vitreous fracture. When put into water, either hot or cold, it softens, and then dissolves, constituting mucilage. Its solubility is increased both by acids and alkalies.

The gums exude from the bark of the trees which produce them, and are collected in small rounded masses. All the varieties may be referred to the two species, *gum-arabic* and *gum-tragacanth*, the latter of which appears not really to dissolve in water, but swells up and forms a thick mucilage. Boiled with dilute sulphuric acid (466), the gums are converted into grape-sugar. The mucilage produced by digesting flax-seed, and the seeds of some other plants, appears to be essentially the same as gum.

468. To what substances is the name gum generally applied? What are some of the properties of gum? From what are they obtained? To what two kinds may all the varieties of gum be referred? How does the composition of gum compare with that of sugar?

WOODY FIBRE, OR LIGNINE ( $C_{12}H_8O_8$ ).

469. This is the basis of wood, and is obtained by digesting saw-dust, or linen or cotton rags, successively in alcohol, ether, diluted acid, diluted alkaline solution, and water, so as to remove every thing that is soluble in these substances. By some, lignine is supposed to contain two organic principles, one of which has the same composition as starch ( $C_6H_{10}O_5$ ), and is called *cellulose*. By the action of sulphuric acid, lignine is converted first into dextrine, and then into sugar, as before explained (466).

When lignine is kept perfectly dry, or constantly immersed in water, it may be preserved for any length of time; but exposed to air and moisture, it undergoes a slow decay, called *eremacausis* (from *erema*, slow, and *kausis*, combustion), by the absorption of oxygen, and the evolution of water or its elements. A variety of other products also results, which constitute most of the organic matter of soils, as *geine*, *humus*, *humic acid*, *ulmine* and *ulmic acid*, and the *crenic* and *apocrenic acids*. These bodies are not as yet very well understood. When lignine is long imbedded in the earth, changes take place in it which are not well understood, and *peat* and the different varieties of *mineral coal* are produced. When it is heated for a time in close vessels, so as to expel every volatile product, we have left nearly pure carbon (233), in the form of *charcoal*.

The mutual relations of starch, sugar, and woody fibre, are singular and important. Their composition, we have seen, is nearly the same; and they are convertible into each

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469. What is woody fibre, or lignine? How may it be kept for any length of time? How is it affected by exposure to the air and moisture? What important substances are produced from it when imbedded deep in the earth? What is said of the mutual relations of starch, sugar, and woody fibre?

other by easy processes; indeed, we are able to recognize this conversion as really taking place, in certain cases, in the natural process of vegetation, as shown in the malting of grain (462). The same change, no doubt, takes place in the ripening of many fruits, as the apple and pear, which are acid until they approach maturity, when they become more or less sweet. The sap of the maple and other trees contain sugar, which subsequently becomes changed into woody fibre, and thus contributes to the enlargement of the tree.

470. *Xyloidine* ( $C_6H_4O_4NO_5$ ) is produced by the action of strong nitric acid upon woody fibre. It may be prepared by dipping a piece of paper in nitric acid of specific gravity 1.5, and immediately washing it with water. It assumes the appearance of parchment, and is so combustible that it may be used for tinder. It may also be prepared from starch.

471. *Gun-Cotton*.—This substance is prepared by soaking cotton for ten or fifteen minutes in a mixture of equal measures of the strongest nitric and sulphuric acids, and immediately washing thoroughly with water, and drying in the open air. For a small experiment, 75 grains of clean, dry cotton may be soaked in a mixture of a measured ounce of each of the acids, care being taken to saturate perfectly the whole of the cotton with the mixed acids. After standing the proper time, as much of the acid is pressed out as possible, and then it is to be washed in a large quantity of water until all trace of acid is removed, and carefully dried in the open air. It is best to dry it without application of any artificial heat, in a place where there is a free circulation of air, and without placing it in the direct rays of the sun.

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470. How is xyloidine formed? What are some of its properties?

471. How is gun-cotton prepared? Does it differ essentially in

When thus prepared, it appears much as before the process, but has a harsh feeling, and the fibres are less tenacious than in the original cotton. It also gains considerably in weight during the process, so that from 75 grains of cotton as much as 115 grains of gun-cotton will often be obtained. It takes fire very readily, often at a temperature even below  $212^{\circ}$ , especially if the heat is suddenly applied; and burns with an immense volume of flame. Placed on a plate of metal, and very gradually heated, it may sometimes be completely decomposed, without igniting, leaving behind a residue of carbon. When ignited in the open air, it is completely consumed, but it does not of itself contain sufficient oxygen entirely to consume its carbon and hydrogen; therefore, when ignited in a confined space, though it explodes with violence, some carbon will remain unconsumed. Its power to propel balls is much greater than that of the best gun-powder, and is rendered still stronger by soaking it in a solution of chlorate of potash before drying. The composition of gun-cotton is uncertain; and different parcels, prepared from the same materials, will occasionally exhibit singular peculiarities, the most striking of which is its behaviour in regard to sulphuric ether, or rather a mixture of sulphuric ether and alcohol, for pure ether is incapable of acting upon it. A parcel of the cotton prepared at one time will be found perfectly soluble in common sulphuric ether (which always contains a portion of alcohol), but another parcel, prepared in the same manner as the first, and from the same materials, will be quite insoluble. This is no doubt owing to slight differences in regard to temperature, or some other circumstance attending the preparation, by

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appearance from common cotton? What is said of its combustion? Does it contain in itself sufficient oxygen for its perfect combustion? What is said of its power to propel balls as compared with gun-powder? Is its composition understood?

which at least two entirely different compounds are produced. It has been observed too that the insoluble kind burns quicker in the open air, and would probably propel a ball more violently than the soluble kind.

The ethereal solution has recently been applied to very useful purposes in surgery.

#### ALCOHOLS, ETHERS, AND SUBSTANCES DERIVED FROM THEM.

472. The substances to be described under this head, though they differ much from each other in many respects, form a natural group, as being derived one from another almost in a very well connected series.

#### WINE ALCOHOL ( $C_4H_6O_2$ ).

473. Common or wine alcohol is always produced by the fermentation of sugar or starch; and the latter substance, before the fermentation takes place, it is believed, always passes into the form of grape-sugar (466); and probably this is true also of cane-sugar. This is called the *vinous fermentation*; and is produced in a solution of sugar, or meal or starch, moistened more or less with water, and kept at a temperature from  $70^\circ$  to  $85^\circ$ , by the addition of yeast, or leaven, or some other active ferment. Instead of yeast, which is only a portion of decomposing starch or sugar, saved from a former operation of the same kind, many other substances will produce the same effect, though not as readily; as blood, or albumen, or the juice of any fruit in a state of incipient decay. The juices of many fruits contain within themselves the necessary ferment; and when

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473. How is common alcohol produced? How may this fermentation be produced in solution of sugar, and other substances? May other substances besides yeast be used as ferments?

expressed from the pulp, they undergo spontaneously the vinous fermentation, as the juices of grapes, apples, currants, &c.

474. The production of alcohol during the process of fermentation is always attended by the continued effervescence of the liquid, occasioned by the escape of carbonic acid, which is formed at the same time with the alcohol, the latter remaining mixed with the water. The production of alcohol and carbonic acid from grape-sugar is very simple, as each atom of this sugar, deprived of its water (466), contains exactly the elements of 2 atoms of alcohol and 4 atoms of carbonic acid. Thus,

Two atoms of alcohol,  $2(\text{C}_4\text{H}_6\text{O}_2)$ , =  $\text{C}_8\text{H}_{12}\text{O}_4$

Four atoms of carbonic,  $4(\text{CO}_2)$ , =  $\text{C}_4\text{O}_8$

One atom of sugar..... $\text{C}_{12}\text{H}_{22}\text{O}_{12}$

It seems therefore that the change which takes place during the fermenting process, resulting in the production of alcohol and carbonic acid, consists only in a rearrangement of the elements of the sugar, induced by the yeast, but without receiving anything from it, or from the air or other source. It would of course be an easy matter to collect the carbonic acid which is evolved during the process and ascertain its exact quantity; and the ingenious student will find it an excellent exercise to devise a mode to accomplish this object.

475. To obtain the alcohol, the solution, after the fermentation has ceased, is to be distilled, which is readily accomplished by any convenient distilling apparatus; but it is to be remembered that the alcohol has been produced

474. What occasions the effervescence always observed in a liquid while fermenting? Into what is sugar converted by the fermenting process? How may the carbonic acid formed in the process be collected?

475. How is the alcohol that is formed separated from the

during the fermentation, and that the only object in distilling is to separate it from the water and other substances with which it is mixed.

Alcohol, as thus distilled, always contains a portion of water, even after several successive distillations. When most highly rectified in this mode, it has a density of about .840, and contains about 90 per cent. of pure alcohol, the rest being water. The alcohol or *spirits of wine* of the shops is never so pure as this. To obtain *absolute alcohol*, or alcohol in a state of purity, common alcohol of the shops is carefully distilled, by the heat of a water-bath, from pearlash or chloride of calcium previously dried and mixed with it. The water combines with the salt and remains behind, while the pure alcohol distils over.

476. Pure alcohol is a colorless liquid, of a pungent taste and odor, and at  $60^{\circ}$  has a density of 0.795. It boils at  $172^{\circ}$ ; and its vapor is highly inflammable, and burns with a pale yellowish flame, without smoke. It has never been frozen by any cold yet produced; but at a temperature of  $-146^{\circ}$ , becomes thick and tenacious, like melted wax.

Alcohol exists in every kind of spirituous liquors, and may be separated from them by distillation. The different kinds of brandy, rum, gin, and whiskey, usually contain from 45 to 55 per cent. of pure alcohol; the stronger wines from 18 to 25 per cent.; and the weaker, not more than 12 or 15 per cent. In cider, ale, and porter, the quantity varies from 4 to 10 per cent.

Alcohol, in some of its forms, is extensively used in the arts and in medicine, chiefly in consequence of its powerful

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water and other substances with which it is mixed? Can alcohol be entirely separated from water by distillation? How is absolute alcohol procured?

476. What are some of the properties of alcohol? What is the proportion of alcohol in some of the varieties of spirituous liquors mentioned?

solvent properties. Taken internally, it operates, as is well known, as a powerful stimulant; and various alarming diseases, often terminating in extreme moral degradation and death, attend its habitual use.

477. *Bread*.—The ordinary mode of bread-making also furnishes an instance of the same kind of fermentation. The flour is made into a paste with water in which a little yeast has been diffused as a ferment; and the dough is put in a place where it will be kept at the proper temperature. In a short time the vinous fermentation commences, and the gradual liberation of carbonic acid through the mass of dough causes it to swell up and become light and porous; and this effect is still further increased by the expanding of the gaseous matter diffused through the dough by the heat during the process of baking. A small portion of alcohol is formed at the same time with the carbonic acid, but it is dissipated by the heat of the oven.

The same thing is sometimes accomplished by the use of an acid and the supercarbonate of potash or soda. The acid, as the tartaric, or hydrochloric, is first mixed with the dough, and then the supercarbonate of soda or potash stirred in; so that a salt is formed by the union of the acid and alkali, attended by the liberation of carbonic acid through the mass of dough, and producing the same effect, to render the bread light and porous, as in the former case.

*Products of the Oxydation of Common or Wine Alcohol, and their Derivatives.*

478. *Aldehyde*,  $C_4H_4O_2$ . Aldehyde (from *alcohol dehydratus*, or *dehydrogenatus*), as will be seen by an inspection

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477. How is flour prepared for bread? What occasions the "rising" of the dough? By what other means is the same thing sometimes accomplished?

478. What is aldehyde? How is the separation of hydrogen



of its formula, is simply alcohol which has lost 2 atoms of its hydrogen. The separation of the hydrogen is effected by the action of nitric acid and other highly oxydized bodies; the hydrogen uniting with oxygen and passing off as water. Its preparation is not difficult, but somewhat complex and tedious.

Aldehyde is a colorless liquid, of a peculiar, suffocating odor; and at  $60^{\circ}$ , has a density of about 0.790. It boils at the low temperature of  $70^{\circ}$ ; and if kept for a short time only, spontaneously changes into two other substances, called *elaldehyde*, which is liquid; and *metaldehyde*, which is solid.

One of the most characteristic properties of aldehyde is its power of reducing oxide of silver. If a small quantity of any liquid containing it is poured into ammonia-nitrate of silver, in a clean glass vessel, and a gentle heat applied, the silver will be immediately reduced, forming a brilliant coating, like a mirror, upon the inside of the glass. Aldehyde is decomposed by solution of an alkali, and a brown resinous substance formed, called *aldehyde resin*.

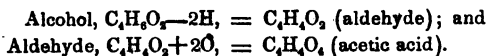
479. *Acetic Acid*— $C_4H_4O_4$ , or  $C_4H_3O_3 + HO$ .—Acetic acid is well known as the acid of *vinegar* (from the French, *vin aigre*, sour wine), which is a very dilute acetic acid, containing also much saccharine and mucilaginous matter. It is prepared by subjecting liquids containing alcohol, as the weaker wines, cider, &c., to the *acetic fermentation*, which always follows the vinous (473), if the liquid is allowed to stand for a time, exposed to the air. The process consists in the abstraction of 2 atoms of hydrogen by the oxygen of the air, forming aldehyde, and the subsequent absorp-

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effected? What are some of its properties? What characteristic property is mentioned? How may silver be precipitated upon the surface of glass by it?

479. What is vinegar? How is it prepared? What is said of

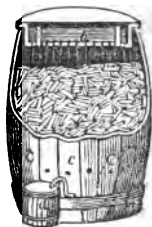
tion of 2 additional atoms of oxygen by the aldehyde. Thus,



The water that is formed by the absorption of oxygen remains in combination with the acid.

The access of atmospheric air is absolutely essential to the formation of vinegar by the ordinary process, as is well known; and its production is much facilitated by a method invented in Germany.

A cask, as shown in the figure, is filled with wood shavings, and closed at top by a pan, *b*, the bottom of which is perforated with many small holes, through which small threads are passed to conduct the liquid downward. The shavings being first well soaked in vinegar, are placed lightly in the cask; and below them are several small holes, *cc*, about half an inch in diameter, to admit the free accession of air. If now proof spirit, diluted with four times its weight of water, and having mixed with it a very little honey or yeast, is poured into the pan above, it gradually trickles down upon the shavings, where, a large surface being exposed to the atmosphere, rapid absorption of oxygen takes place, the temperature is raised, and acetic acid is rapidly formed. As the liquid passes down, it is collected in the vessel *a*; and when passed through three or four times, which requires but about 36 hours, it is converted into excellent vinegar.



Acetic acid cannot be separated from water by mere distillation, as both liquids distil over together; but the pure acid is obtained by distilling some acetate, as acetate of

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the acetic fermentation? Describe the changes that take place in this fermentation. Describe the mode of producing vinegar practised in Germany. How is pure acetic acid procured?

soda or lime, with a proper quantity of sulphuric acid, and collecting the product in a cold receiver.

480. *Wood-vinegar*, or *pyroligneous acid*, is obtained by distilling wood in close vessels. It is a very impure acetic acid, having a disagreeable smoky odor, and containing empyreumatic oils and other substances derived from the wood. It is much used in calico-printing; and often the cloths, not having been properly cleansed, possess its disgusting odor. By neutralizing it with lime, and distilling with sulphuric acid, pure acetic acid is obtained.

Pure acetic acid, at  $63^{\circ}$ , is a colorless liquid, of a pungent refreshing odor, and excessively sour to the taste. Applied to the skin for a time, it produces blisters. It boils at  $248^{\circ}$ ; and cooled below  $63^{\circ}$ , it may be obtained in crystals. At  $63^{\circ}$ , the density of the liquid is 1.06. It mixes readily with water, ether, or alcohol.

481. *Acetal* ( $C_8H_{10}O_3$ ) contains the elements of one atom of aldehyde and one of ether (soon to be described); and is formed by the action of moistened platinum block (445) upon a mixture of vapor of alcohol and oxygen, in a large bell-glass. It is a colorless liquid, which boils at about  $203^{\circ}$ , and has a density of about 0.825.

### *Salts of Acetic Acid.*

482. Acetic acid combines with most bases, forming salts called acetates. In combination, its composition is  $C_4H_3O_3$ ; from which it appears that in the process of combining, one atom of water,—or the elements of water,—is given up.

480. What is wood-vinegar or pyroligneous acid? What use is made of it? What are some of the properties of pure acetic acid?

481. How is acetal formed?

482. What change takes place in this acid as it enters into combination with bases?

A few only of the more important acetates will be here noticed.

483. *Acetate of Lead*— $\text{PbO}, \text{C}_4\text{H}_3\text{O}_3$ .—This is the *sugar of lead* of commerce. It is formed by dissolving oxide of lead (litharge) in acetic acid. When crystalized, it contains 3 atoms of water. It is soluble in pure water, and has a sweet, astringent taste. Taken internally, it is poisonous; but is used in various preparations in medicine.

Besides the above, there are several other acetates of lead, as the sesquibasic, tribasic, and sexbasic, which are formed by the union of additional portions of oxide of lead with the above neutral acetate.

484. *Acetate of Copper*— $\text{CuO}, \text{C}_4\text{H}_3\text{O}_3$ .—Acetate of copper is obtained by dissolving oxide of copper in the pure acid. It forms fine green crystals, which contain one atom of water, and is sometimes called *distilled verdigris*. There are also a sesquiacetate and a tribasic acetate of copper; and the *verdigris* of commerce, used as a paint, appears to be a mixture of the two. It is prepared in large quantities in the south of France, by covering copper with the refuse of grapes, after the juice has been extracted for making wine: the saccharine matter contained in the husks furnishes acetic acid by fermentation, and in four or six weeks the plates acquire a coating of the acetate. A purer and better article is prepared by covering copper plates with cloth soaked in pyroligneous acid.

485. *Acetate of Alumina* is prepared by decomposing solution of sugar of lead by one of alum. It is used in dyeing. *Acetates of potash and soda* are readily obtained by dissolving the carbonates of these bases in the diluted

483. What is sugar of lead? How is it formed?

484. How is acetate of copper formed? What is the common name by which it is known?

485. What use is made of acetate of alumina?

acid. *Acetate of iron* is formed by digesting iron-filings in the acid, or decomposing green vitriol by acetate of lead. Other acetates may be procured by similar modes.  $\gamma$

*Derivatives of Acetic Acid and the Acetates.*

486. *Chloracetic Acid*— $C_2H_3O_2Cl_3$ .—This acid is formed from acetic acid, by the abstraction of 3 atoms of its hydrogen and the substitution of 3 atoms of chlorine. It is prepared by placing some crystals of acetic acid under a large bell-glass filled with chlorine, and exposing it to the direct rays of the sun. It is crystalizable, and in most of its properties resembles acetic acid. It boils at about  $200^\circ$ .

487. *Acetone*— $C_3H_6O$ .—Acetone, or *pyroacetic spirit*, is a limpid liquid, obtained by passing vapor of acetic acid through a red-hot tube, or by distilling dry sugar of lead, and condensing the product in a cool receiver. Much uncondensable, gaseous matter passes over at the same time, which is allowed to escape. It has a density of 0.792, and boils at  $132^\circ$ .

488. *Alcarsine* ( $C_4H_4AsO$ ) is a substance obtained by distilling a mixture of equal parts of acetate of potash and arsenious acid, and sometimes called *Cadet's fuming liquor*. When pure, it is a colorless liquid, which boils at about  $300^\circ$ , and has a density of 1.46. It is corrosive to the flesh and poisonous; and is capable of uniting with the acids, like the vegetable alkalies, forming salts.

489. Alcarsine is the oxide of a principle ( $C_4H_4As$ ) which has received the name of *kakodyle* (*kakos*, evil, and *ule*, principle), and which may be obtained in a separate state

486. What is the composition of chloracetic acid?

487. What is acetone? What are some of its properties?

488. What is alcarsine? What are some of its properties?

489. Of what is alcarsine the oxide? What is chlorarsine?

as a colorless liquid. It fumes in the open air and takes fire spontaneously, and is exceedingly poisonous.

By digesting alcarsine in hydrochloric acid, the compound,  $C_4H_6AsCl$ , is obtained, in which it is evident chlorine replaces the oxygen of the alcarsine. It is a poisonous liquid, and has been called *chlorarsine*, and chloride of kakodyle. In the same manner, iodine, sulphur, and cyanogen, may be made to unite with this substance, which evidently serves as a distinct compound radical.

By the gradual oxydation of kakodyle or alcarsine, the tritoxide of kakodyle ( $C_4H_6AsO_3$ ) is formed, which has been called *alcargen*, and *kakodylic acid*.

#### METHYLIC ALCOHOL, OR WOOD-SPIRIT ( $C_2H_4O_2$ ).

490. This substance is obtained by distilling wood in close vessels, and is collected with the pyroligneous acid heretofore described (480). By neutralizing the crude acid with lime, and re-distilling, the spirit passes over, which however is still impure, and requires to be several times rectified. It is called, in commerce, *pyroxylic spirit* (from *pur*, fire, and *xulon*, wood); but from its resemblance to common alcohol it is more properly designated by the name used above, methylic alcohol (from *methu*, wine, and *xulon*, wood).

Methylic alcohol is a colorless liquid, with an odor and taste resembling those of common alcohol. It has a density of 0.798, and boils at  $152^\circ$ ; and burns freely in a lamp.

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490. From what is methylic alcohol or wood-spirit obtained? What is the derivation of the name? What are some of its properties?

*Products of the Oxydation of Methylic Alcohol.*

491. *Formic Acid*— $C_2H_2O_4$ .—This acid was first obtained by disillation from the bodies of red ants (*formica rufa*); and hence its name. Its relation to methylic alcohol is the same as that of acetic acid to common alcohol. It may be obtained by exposing the vapor of wood-spirit, mixed with air, to the action of platinum black (445), under a receiver; water and formic acid being produced at the same time. Two atoms of oxygen combine with 2 atoms of the hydrogen of the spirit, forming 2 atoms of water; and then 2 atoms more of oxygen unite with the residue to form the acid. Thus, wood-spirit,  $C_3H_4O_2 + O_2 = C_3H_2O_2 + 2HO$ ; and  $C_3H_2O_2 + 2O = C_2H_2O_4$  (formic acid).

492. Formic acid may also be produced by distilling a mixture of sugar, bichromate of potash, and oil of vitriol; but to obtain it pure, the process is tedious. It is a clear liquid, of specific gravity 1.24; has a strong acid taste and odor, and quickly produces blisters upon the skin. It boils at  $212^\circ$ , and crystalizes at  $32^\circ$ . When this acid combines with bases, like acetic acid, it gives up the elements of an atom of water; and is therefore by many considered as a hydrate, and its formula written  $C_2HO_3 + HO$ .

Formic acid combines with many of the bases, forming salts which closely resemble the acetates.

493. *Methylal*— $C_6H_8O_4$ .—This substance is procured by distilling a mixture, in proper proportion, of methylic alcohol, dilute oil of vitriol, and peroxide of manganese, and purifying the product. It is a colorless liquid, of an agree-

491. Why has formic acid received this name? How may it be obtained? What are the chemical changes that take place in the process?

492. How may it be formed from sugar? What are some of its properties?

493. How is methylal procured?

able aromatic odor, and burns with a yellow flame. It has a density of 0.85, and boils at  $108^{\circ}$ .

*Other Derivatives of Methylic Alcohol.*

494. *Chloroform*— $\text{C}_2\text{HCl}_3$ .—Chloroform is prepared by distilling a mixture of solution of common bleaching-salt (337) and common alcohol, or wood-spirit. It may also be formed by several other modes. Chloroform is a dense, oily liquid, of an agreeable ethereal odor, and sweetish taste. It is not dissolved by water, but mixes readily with alcohol. Its density is 1.48, and it boils at about  $141^{\circ}$ . By breathing its vapor mixed with atmospheric air, a kind of intoxication is produced, much like that occasioned by exhilarating gas, or the vapor of sulphuric ether.

By alcoholic solution of potash, chloroform is changed into formiate of potash and chloride of potassium. It was this circumstance that suggested the name chloroform.

495. *Iodoform* ( $\text{C}_2\text{HI}_3$ ) and *bromoform* ( $\text{C}_2\text{HBr}_3$ ) are analogous compounds, containing iodine and bromine.

AMYLIC ALCOHOL ( $\text{C}_{10}\text{H}_{18}\text{O}_2$ ).

496. Amylic alcohol is a peculiar oily substance, which is collected in the process of distilling spirit from potatoes. It is supposed to be formed from the starch (*amylum*) of the potatoes, and hence its name. It is also called *potato-oil*, and *fusel oil*. It is a colorless liquid, insoluble in water; and of a pungent suffocating odor, and burning taste. It boils at  $269^{\circ}$ , and has a density of 0.82.

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494. How is chloroform prepared? Describe it. What effect is produced by breathing its vapor?

495. What is iodoform?

496. What is amylic alcohol? By what other names is it known? Describe it.



*Product of the Oxydation of Amylic Alcohol.*

497. *Valerianic Acid*— $C_{10}H_{10}O_4$ .—This acid is contained in the valerian root (*valeriana officinalis*), which is extensively used in medicine, and is obtained by distilling the root with water. It is also formed artificially by dropping warm potato-oil upon platinum black in contact with atmospheric air, and by other modes. During the process, much oxygen is absorbed, and the water and the acid in question produced. Thus,  $C_{10}H_{12}O_2 + 2O = C_{10}H_{10}O_2 + 2HO$ ; and  $C_{10}H_{10}O_2 + 2O = C_{10}H_{10}O_4$ .

498. Pure valerianic acid is a colorless, oily liquid, of specific gravity 0.935. Its taste is pungent and acid, and its odor like that of valerian. Its boiling point is  $347^\circ$ .

Valerianic acid, in this group, corresponds to acetic acid in the common alcohol group, and to formic acid in the methylic alcohol group. It combines with bases, forming salts in many respects similar to the acetates and formates. When it enters into combination, it gives up the elements of one equivalent of water, precisely like the acetic and formic acids.

SULPHUR ALCOHOL, OR MERCAPTAN ( $C_4H_6S_2$ ).

499. This substance has the same composition as common alcohol ( $C_4H_6O_2$ ), except that the two atoms of oxygen are replaced by two atoms of sulphur. The other alcohols are all distinguished by containing two atoms of oxygen

497. In what is valerianic acid found? How may it be formed artificially?

498. Describe it. What is the relation of valerianic acid in this group as compared with other groups?

499. What is said of the composition of sulphur alcohol? How

united with carbon and hydrogen;—and the hydrogen also exceeds the carbon by two atoms.

Mercaptan is formed by saturating a solution of caustic potash, of density 1.3, with sulphuretted hydrogen, and distilling it with an equal measure of sulphovinate of lime (a substance to be hereafter described) of the same density. It is a colorless liquid, which has a specific gravity of about 0.84, and boils at  $97^{\circ}$ . Its odor resembles that of onions. It is distinguished for its strong affinity for mercury, with which it forms a solid compound. It is from this circumstance it derives the name, mercaptan (*mercurium captans*), by which it is more generally known. The mercury, in the compound, takes the place of one equivalent of the hydrogen, so that its composition is  $C_4H_5HgS_2$ .

## ETHERS.

500. We designate by this name quite a numerous class of very volatile liquids, which are formed, in most cases, by distilling a mixture of alcohol with some acid, as the sulphuric, nitric, acetic, &c. The name was suggested by their volatility, which seems to be an essential characteristic; but they differ from each other very materially in their composition, some of them being entirely destitute of acid, and others being of the nature of salts, and of course containing a portion of acid as an essential ingredient. Whether containing acid or not, an ether is usually named from the acid made use of in forming it.

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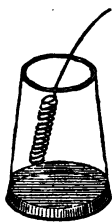
are all the other alcohols distinguished? By what other name is this substance known? How is it formed? Describe it. Why has it been called mercaptan?

500. What is said of the ethers? What property have they which has suggested the name? What is said of their compositions?

*Ethers derived from Common Alcohol.*

501. *Sulphuric Ether*— $C_4H_{10}O$ .—Sulphuric ether may be formed by several modes; but the best is to distil a mixture of equal parts of alcohol and strong sulphuric acid in a glass retort, the process being discontinued as soon as the mixture begins to turn black. For a small experiment, the distilling apparatus figured on page 49 will answer; but if a large quantity is to be prepared, a more powerful still is required. The product should be washed with water, to separate a little alcohol and sulphurous acid that usually pass over with the ether. This is done by filling a bottle about half full with the impure ether, and then pouring in about half as much water, and shaking them well together. After standing a few minutes, the liquids separate, and the water may be drawn off by perforating the cork and inverting the bottle, taking care to notice when the water has all escaped.

502. Pure sulphuric ether is a colorless liquid, of a hot, pungent taste, and fragrant odor. At the temperature of  $60^{\circ}$ , its density is 0.72, and it boils at  $96^{\circ}$  or  $98^{\circ}$  in the atmosphere, or at about  $40^{\circ}$  below zero in a vacuum. In the open air, it evaporates with great rapidity, producing intense cold, so that water may easily be frozen (94) by it. With atmospheric air, its vapor forms an explosive mixture; and a coil of platinum wire, heated and suspended in a deep vessel containing a little of it, instantly begins to glow with a red heat, and continues in this state until the ether has all evaporated. It is very combustible, and burns with a yellow




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501. What is the mode described for forming sulphuric ether? Why is it necessary to wash the ether after it is formed?

502. Describe sulphuric ether. Describe the experiment with a coil of platinum wire.

flame. Exposed to the light, in vessels partly filled with air, it gradually absorbs oxygen, with the formation of acetic acid. The solvent powers of ether are not as extensive as those of alcohol, but it dissolves the essential oils, resins, and many of the fatty principles.

503. When the vapor of ether is inhaled, it first produces a species of intoxication, similar to that occasioned by exhilarating gas (225); and afterwards a kind of stupor follows, during which the person is nearly insensible to pain; and difficult surgical operations may often be performed upon a person under its influence, not only without pain, but even without his knowledge. When used for this purpose, it has been called *letheon*.

By the formula of this substance ( $C_4H_6O$ ), it will be observed that it contains no acid, but it is called sulphuric ether merely from the fact that sulphuric acid is used in preparing it. Often the prefix, sulphuric, is omitted; and the word ether, when used alone, is always to be understood as referring to this liquid.

504. *Theory of the Formation of Ether. Sulphovinic Acid.*—By comparing the formula of alcohol ( $C_4H_6O_2 = C_4H_6O + HO$ ) with that of ether ( $C_4H_6O$ ), it will be seen that the former substance may be considered as a hydrate of the latter; and the effect of the acid upon the alcohol in producing ether is simply to abstract from it one equivalent of water, or its elements. But although this is the final result, various other intermediate chemical changes take place.

When equal parts of sulphuric acid and alcohol are mixed

503. What is the effect produced by inhaling ether? What is it called when used for this purpose? Does this ether contain any acid? Why then is it called sulphuric ether?

504. What is the change produced by the acid upon the alcohol in converting it into ether? Do other intermediate changes take

and heated slightly, the compound, bisulphate of ether is formed ( $C_4H_8O, 2SO_3, 2HO$ ), which is called the *sulphovinic acid*; and, by a complicated process, it may be obtained in a free state, as a syrupy liquid. It is capable of combining with bases to form salts. Heated to the boiling point, this acid is decomposed, and the ether distils over as before explained, while the acid and water remain behind. By using alcohol of proper strength, and regulating the temperature very accurately, at a little below  $300^\circ$ , both the ether and the water which are formed may be made to distil over together; and thus a small quantity of acid will suffice to decompose a large quantity of alcohol. Phosphoric and arsenic acids act upon alcohol in the same manner, producing *phosphovinic* and *arsenovinic acids*.

Acids of this kind are sometimes called *coupled acids*, as they consist of a common acid coupled or united with another substance. They always possess the same neutralizing power as the acid from which they are formed. The sulphovinic acid, for instance, will neutralize just the same quantity of soda or other base as the sulphuric acid contained in it would neutralize.

Neutralized with bases, sulphovinic acid produces salts, called sulphovinates, several of which may be crystalized. Sulphovinate of lime is used in preparing sulphur alcohol.

505. *Hydrochloric Ether*— $C_4H_8Cl$ .—This ether is prepared by saturating alcohol with hydrochloric acid gas, and distilling with a very moderate heat, in an apparatus so contrived that the vapor is conveyed through warm water to a very cold receiver. It is a colorless liquid, which boils

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place in it? What is sulphovinic acid? May it be obtained in a free state? When this acid is heated to the boiling point, what is the effect produced? May other acids of a similar character be formed? What are they called?

505. How is hydrochloric ether prepared? Describe it.

at the low temperature of  $52^{\circ}$ , and has a density of 0.87. By its formula it will be seen that its composition is the same as that of sulphuric ether, except that the oxygen of the latter substance is replaced by chlorine. Bromine and iodine form similar ethers.

506. *Hyponitrous Ether* —  $C_4H_5O,NO_3$ , or  $C_4H_5NO_4$ . — This ether may be formed by the direct action of nitric acid upon alcohol; but a better mode is to pass a current of nitrous acid vapor (obtained by the action of nitric acid upon starch) through dilute alcohol. Heat is generated by the process, and the vapor is condensed in a cold receiver. Hyponitrous ether is a liquid of a pale yellow color, and fragrant odor; its density is about 0.948, and it boils at  $62^{\circ}$ . In a pure state it cannot be kept long; but mixed with alcohol it is more permanent, and is extensively used in medicine, under the name of *sweet spirits of nitre*.

507. *Nitric Ether* —  $C_4H_5O,NO_3$ , or  $C_4H_5NO_6$ . — Nitric ether is formed by distilling equal parts of nitric acid and alcohol with a few grains of nitrate of urea. It is a colorless liquid, of a sweet taste, and is heavier than water. It boils at  $185^{\circ}$ ; and its vapor explodes by heat.

508. *Acetic Ether* —  $C_3H_5O_4$ , or  $C_4H_5O,C_2H_3O_3$ . — This ether may be formed by different modes; but it is best obtained by distilling a mixture of 3 parts of acetate of potash, 3 of absolute alcohol, and 2 of sulphuric acid. Acetic ether is a volatile liquid, of a fragrant odor, like that of strong vinegar. It boils at  $165^{\circ}$ , and has a density of about 0.89.

509. *Oxalic ether* ( $C_2H_2O_4 = C_4H_2O,C_2O_3$ ) is prepared by distilling a mixture of 4 parts of binoxalate of potash, 5

506. How is hyponitrous ether formed? What is it sometimes called?

507. What is the composition of nitric ether?

508. How is acetic ether formed?

509. How is oxalic ether formed?

parts of sulphuric acid, and 4 of strong alcohol, and thoroughly washing the product with water. It is a volatile liquid, which has an aromatic odor, and is a little heavier than water.

As before intimated (500), the last three or four ethers have the composition of salts; that is, they are each composed of an acid united with sulphuric ether ( $C_4H_6O$ ), which serves as a base. They however differ essentially from saline compounds, as the acid in them cannot be detected by the ordinary tests. The same is true of the coupled acids, shortly to be described. Thus, oxalic ether is a compound of sulphuric ether ( $C_4H_6O$ ) and oxalic acid ( $C_2O_3$ ); but lime, which separates oxalic acid from its saline compounds, forming oxalate of lime, will not separate this acid from oxalic ether.

There are several other ethers belonging to this class, as the carbonic, formic, ænanthic, &c.; but the limits prescribed to this work do not allow their introduction here.

### *Ethers derived from Methylic Alcohol.*

510. *Methylic Ether—Wood-Ether*,  $C_2H_5O$ .—This ether is formed from methylic alcohol (490), in the same manner as sulphuric ether is prepared from common alcohol, by distilling methylic alcohol with 4 times its weight of sulphuric acid. It is a colorless gas, of a pungent odor and taste, and is rapidly absorbed by cold water, but given off again unchanged by boiling. It is chiefly interesting as taking the place, in this series, which sulphuric ether occupies in the common alcohol series. By using 8 or 10 parts of sulphuric acid to 1 of wood-spirit, a liquid ether is obtained ( $C_2H_5O, SO_3$ ) which has no corresponding compound in the common alcohol series.

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510. What is methylic ether?

511. *Hydrochloric Methylic Ether*— $C_2H_5Cl$ .—This compound is formed by distilling a mixture of common salt, wood-spirit, and oil of vitriol. It is a colorless gas, of a peculiar odor, and corresponds to the ether of similar name (505) in the common alcohol series.

512. *Nitric Methylic Ether* ( $C_2H_5O, NO_2$ ) corresponds to the ether of similar name in the common alcohol series. It is formed by distilling a mixture of wood-spirit, nitrate of potash, and sulphuric acid. It is a dense, colorless liquid, which boils at about  $150^\circ$ .

In like manner oxalic acid forms *oxalic methylic ether* ( $C_2H_5O, C_2O_3$ ). It is prepared by distilling wood-spirit, oxalic acid, and oil of vitriol. It may be obtained in white crystals, which become liquid at about  $124^\circ$ , and the liquid boils at  $322^\circ$ .

### *Ethers derived from Amylic Alcohol.*

513. A very close analogy exists between common alcohol and amylic alcohol, as well as their corresponding compounds and derivatives; but the proper amylic ether, supplying the place of sulphuric ether in the common alcohol series, has not yet been described, though it is believed it has been obtained.

514. *Hydrochloric Amylic Ether*— $C_{10}H_{11}Cl$ .—This ether is obtained by distilling equal parts of perchloride of phosphorus and amylic alcohol, and purifying the product. It is a liquid, which boils at  $215^\circ$ , and has an agreeable aromatic odor.

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511. What is hydrochloric methylic ether?

512. How is nitric methylic ether formed?

513. What is said of the analogy between common alcohol and amylic alcohol?

514. What is the composition of hydrochloric amylic ether?



515. *Acetic Amylic Ether*— $C_{14}H_{14}O_4$ , or  $C_{10}H_{11}O, C_4H_5O_3$ .—This ether, which is a colorless liquid, boiling at  $257^\circ$ , may be procured by distilling a mixture of acetate of potash, amylic alcohol, and sulphuric acid.

*Relation of the Preceding Compounds on the Compound Radical Theory.*

516. A compound radical, as we have heretofore (455) seen, is a compound substance, which is capable, in many cases, of performing the office of an element, or proper radical. That there are such compounds, is very certain, a few (and only a few) having been procured in a separate state; but if we assume the existence of others in combination, which may perhaps never be found capable of isolation, we are often able to group together numerous compounds, as having a very simple relationship, which otherwise appear to be entirely isolated from each other.

Thus, *ethyle* (from *ether*, and *ule*, principle) is a name applied to the ideal compound  $C_4H_5$ , which is supposed to serve as the base or radical of a long series of compounds, many of which have been described in the preceding pages. Their relation to each other, on this hypothesis, will be seen by the following table:

|                                                          |                                  |
|----------------------------------------------------------|----------------------------------|
| Ethyle .....                                             | $C_4H_5$                         |
| Oxide of ethyle (ether) .....                            | $C_4H_5O$                        |
| Hydrate of oxide of ethyle (alcohol) ...                 | $C_4H_5O_2 = C_4H_5O + HO$       |
| Chloride of ethyle (hydrochloric ether) ..               | $C_4H_5Cl$                       |
| Bromide of ethyle (hydrobromic ether).                   | $C_4H_5Br$                       |
| Hyponitrite of oxide of ethyle (hyponitrous ether) ..... | $C_4H_5NO_2 = C_4H_5O + NO_2$    |
| Nitrate of oxide of ethyle (nitric ether) ..             | $C_4H_5NO_3 = C_4H_5O + NO_3$    |
| Acetate of oxide of ethyle (acetic ether)                | $C_4H_5O_4 = C_4H_5O, C_2H_3O_2$ |

515. State the method of preparing acetic amylic ether.

516. What is a compound radical? Have any of these been obtained in a separate state?

The list might be extended much further;—and this view of the relation of the substances included in the series gives to it a singular simplicity, which however, unfortunately, is its chief recommendation.

A second series may be formed of the derivatives of common alcohol by assuming the compound  $C_4H_9$  (called *acetylc*) as a radical or basis. We then have the following:

Acetylc.....  $C_4H_9$   
 Oxide of acetylc (unknown).....  $C_4H_9O$   
 Hydrated oxide of acetylc (aldehyde)  $C_4H_9O_2=C_4H_9O,HO$   
 Acetous acid—Aldehydic acid.....  $C_4H_9O_3=C_4H_9O_2,HO$   
 Acetic acid .....  $C_4H_9O_4=C_4H_9O_3,HO$

Methylic alcohol, in like manner, affords a series of compounds similar to the first of the foregoing. Methyle, the radical, like ethyle and acetylc, is an ideal substance, having never been obtained in a separate state.

Methyle.....  $C_2H_5$   
 Oxide of methyle (methylic ether)....  $C_2H_5O$   
 Hydrated oxide (methylic alcohol) ....  $C_2H_5O_2=C_2H_5O,HO$   
 Chloride of methyle (hydrochloric methylic ether) .....  $C_2H_5Cl$   
 Nitric methylic ether.....  $C_2H_5O,NO$

The following series is derived from amylic alcohol. The supposed radical of the series is amyle ( $C_{10}H_{21}$ ), which has not been obtained in a separate state.

Amyle .....  $C_{10}H_{21}$   
 Oxide of amyle (unknown) .....  $C_{10}H_{21}O$   
 Hydrated oxide of amyle (amylic alcohol)  $C_{10}H_{21}O_2=C_{10}H_{21}O,HO$   
 Hydrochloric amylic ether .....  $C_{10}H_{21}Cl$

## OIL OF BITTER ALMONDS, AND SUBSTANCES DERIVED FROM IT.

517. *Oil of Bitter Almonds*— $C_{14}H_{10}O_2$ .—This volatile oil is obtained from the kernels of bitter almonds by distillation with water after the fixed oil contained in the seed has been expressed. Its density is a little above that of water, and it boils at  $356^\circ$ . It is quite colorless, and has a pungent taste and fragrant odor, and is poisonous. It is a very interesting substance, from the fact that from it a long series of other compounds is derived, amounting to thirty or more in number. A very few only will be noticed.

518. *Benzoic Acid*— $C_{14}H_{10}O_4$ .—This acid, which is a white crystalline solid, is rapidly formed from bitter almond oil when it is exposed to the air, by the absorption of oxygen; and may also be obtained by sublimation from *gum-benzoin*, and by other processes. Exposed to a heat of  $212^\circ$ , the crystals melt, and the liquid so produced boils at  $462^\circ$ . The sublimation of this acid may be beautifully



shown by putting a small quantity of it upon a plate of metal on a stand and placing over it a glass receiver, having suspended in it a small twig of mint or other substance, as shown in the figure, and applying the heat of a lamp beneath it. In a short time the leaves will be covered with delicate crystals of the acid.

Benzoic acid combines with numerous bases, forming salts, which are called *benzoates*.

519. *Hippuric Acid*— $C_{13}H_9NO_6$ .—This acid is formed in the urine of certain herbivorous animals, and in that of

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517. How is the oil of bitter almonds extracted? Describe its properties.

518. How is benzoic acid formed? From what gum may it be obtained? How may the sublimation of this acid be shown?

519. How is hippuric acid formed?

man, especially after benzoic acid has been taken into the stomach, but it has not been formed artificially. It is a crystalline solid. By boiling it with oil of vitriol, it is decomposed, and benzoic acid is produced.

520. *Chloride of Benzyle*— $C_{14}H_5O_2Cl$ .—This substance is obtained by passing a current of dry chlorine through oil of bitter almonds, and expelling the excess of chlorine by heat. It is a colorless liquid, heavier than water, and has a peculiar, disagreeable odor. It is formed from the oil by the substitution of an atom of chlorine for one of hydrogen. Iodine and bromine form similar compounds.

521. *Benzoine*— $C_{14}H_5O_2$ , or  $C_{28}H_{12}O_4$ .—This compound, it will be perceived, has the same composition as the oil of bitter-almonds, and is therefore said to be isomeric (200) with it. It is a crystalline solid, and is formed from the oil by the action of caustic potash. By passing its vapor through a red-hot tube, the oil is reproduced.

Those who adopt the compound radical theory, consider these substances, and the others derived from bitter-almond oil, as compounds of an ideal radical ( $C_{14}H_5O_2$ ) called *benzyle*, of which the oil itself ( $C_{14}H_5O_2$ ) is a hyduret, benzoic acid ( $C_{14}H_5O_4 = C_{14}H_5O_2 + O + HO$ ) the hydrated oxide, &c.

Benzamide, hydrobenzamide, sulphobenzide, nitrobenzide, sulphobenzoic acid, benzene, &c., are other similar compounds, derived from the same oil.

#### SALICINE, AND BODIES DERIVED FROM IT.

522. *Salicine*— $C_{21}H_{13}O_{11}$ .—Salicine is obtained chiefly from the bark of certain species of the willow (*salix*), but is contained in many other plants. It is a white crystalline

520. How is chloride of benzyle formed? What chemical change takes place during its formation?

521. What is benzoine? What are some of its properties?

522. From what is salicine obtained?

solid, very soluble in hot water, and of a bitter taste. It is used in medicine.

523. *Oil of Spiræa*— $C_{14}H_8O_4$ .—This compound is obtained by distilling a mixture of salicine, oil of vitriol, and bichromate of potash, and also from the leaves of the *spiræa ulmaria* (pride of the meadow), by distilling them with water. It is a transparent liquid, which boils at about  $364^\circ$ , and has a density of 1.173. It is isomeric with benzoic acid.

524. *Salicylic Acid* ( $C_{11}H_8O_6$ ) is procured by heating the above oil with caustic potash. It is a white, volatile solid.

525. *Oil of Wintergreen*.—This oil, well known in this country, is obtained by distilling the leaves and berries of the common wintergreen (*gaultheria procumbens*) with water. It may also be prepared by distilling a mixture of salicylic acid, wood-spirit, and oil of vitriol.

On the compound radical theory, salicine and its derivatives are considered as formed by different modes from the ideal radical *salicyle*, the composition of which is  $C_{14}H_8O_4$ .

526. The essential *oil of cinnamon*, which is derived from the bark of the cinnamon-tree, like the oil of bitter almonds, serves as the basis from which a number of analogous compounds are obtained. Its composition is  $C_{18}H_8O_2$ . When exposed to the air it absorbs oxygen, and an acid called *cinnamic acid* ( $C_{18}H_8O_4$ ) is formed. This acid may be obtained in crystals, which melt at about  $264^\circ$ ; and the liquid boils at about  $554^\circ$ . It is soluble both in water and alcohol. Several other compounds are produced from it. Both cinnamic and benzoic acids are contained in *balsam of Tolu*.

523. From what is oil of spiræa obtained?

524. What is salicylic acid?

525. What is said of oil of wintergreen?

526. What is said of oil of cinnamon?

# VEGETABLE ACIDS NOT INCLUDED IN ANY OF THE PRECEDING GROUPS.

527. *Oxalic Acid*— $C_2HO_4=C_2O_3,HO$ .—Oxalic acid, in combination with bases, is found in many plants, especially in certain species of the sorrel (*oxalis*), and also in certain minerals. It may likewise be prepared artificially, by digesting starch, or sugar, with nitric acid, and by other processes.

Pure oxalic acid is a crystalline solid, in external appearance not unlike Epsom salt, for which it has sometimes been mistaken. It is very soluble in water, and exceedingly sour to the taste. Taken into the system, it is very poisonous. It is bibasic;—that is, it tends to form salts in which two atoms of base are in combination with one atom of the acid.

528. Oxalic acid forms numerous salts with the different bases. *Oxalate of lime* is a white powder, quite insoluble in water, and is found as a mineral production, and in many plants, in the cells of which the crystals may often be detected by the microscope. With potash it forms three salts; the *oxalate*, which is soluble, and is found in many plants of a sour taste, the *binoxalate*, and the *quadroxalate*. The last two are much less soluble than the first. These salts of potash, especially the first, are often used to remove stains of iron-rust or ink from linen. *Oxalate of ammonia* is much used in chemical analyses.

529. *Tartaric Acid*— $C_4H_6O_6=C_2H_4O_4,2HO$ .—Tartaric acid, in combination with potash, exists in many fruits, especially in grapes. When the expressed juice of the

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527. In what is oxalic acid found? How may it be prepared artificially? What are some of its properties?

528. What are some of the oxalates mentioned?

529. In what is tartaric acid contained? Describe it.

grape is fermented, as in the manufacture of wine, this salt, in an impure state, is precipitated upon the inside of the cask, as *argol*, or *tartar*. From this the pure acid is obtained, which is a white solid, very soluble in water, and of an agreeable acid taste. Like oxalic acid, it is bibasic.

530. Tartaric acid forms with potash two salts, the neutral *tartrate*, and the acid or *bitartrate*. The latter is well known as *cream of tartar*. By saturating a solution of cream of tartar with soda, the double tartrate of potassa and soda is formed, which is often called *Rochelle salt*. *Tartar emetic* is a double tartrate of potash and antimony.

531. *Citric Acid*— $C_{12}H_5O_{14} = C_{12}H_5O_{11} + 3HO$ .—Citric acid is obtained chiefly from the lemon (*citron*), but is found in other fruits. When pure it forms crystals, which are very soluble in water, and have an agreeable sour taste. It is used in calico-printing, and for medicinal and domestic purposes.

Citric acid is tribasic;—that is, its salts contain three atoms of base united with one atom of acid; but one or two atoms of the base may be water. In bibasic acids, one of the atoms of base may in like manner be water. The salts of citric acid are unimportant.

532. *Malic Acid*— $C_8H_7O_{10} = C_8H_7O_8 + 2HO$ .—This acid is found in the apple (*malum*) and other fruits, as the currant and gooseberry. When pure it forms crystals, which are very soluble in water, and are sour to the taste. It is bibasic.

533. *Tannic Acid*— $C_{18}H_8O_{12} = C_{18}H_8O_9 + 3HO$ .—Tannic acid occurs in the bark and leaves of many trees, as the oak,

530. What are some of the tartrates mentioned? What is *cream of tartar*?

531. From what is citric acid obtained?

532. What is malic acid found in?

533. In what does tannic acid occur? How is it procured from

chestnut, and hemlock, but is especially abundant in *nut-galls*, which are excrescences that form upon the leaves of several species of the oak. To prepare it, nut-galls, in coarse powder, are introduced into a funnel, of the form A, represented in the figure, the mouth having been loosely filled with a little cotton, and pouring over them some sulphuric ether that has been previously washed. The funnel is placed in a vessel of the form B, into which the liquid gradually percolates, and separates spontaneously into two portions, the lower of which is a solution of tannic acid in water (a little of which was contained in the ether) with ether above it. The acid solution can be easily separated; and by evaporation yields the tannic acid as a solid mass.



This acid is soluble in water, and has a peculiar astringent taste. It is a feeble acid, but forms salts with bases. With salts of the peroxide of iron, it forms a deep blue or black precipitate, which is the basis of writing-ink.\* It forms an insoluble and very important compound with gelatine, which is the basis of leather. Raw hides, after the hair is removed, are soaked for a time in a decoction of bark which contains this substance, by which they are changed into leather.

534. *Gallic Acid* ( $C_7H_3O_5 = C_7HO_3 + 2HO$ ) is formed

\* To prepare an excellent black writing-ink, pour 6 pints of boiling rain-water upon 6 ounces of the best nut-galls in powder, and add 4 ounces of gum-Arabic, and let the whole stand two days in a wooden or earthen vessel. Then strain the liquid and mix with it 4 ounces of clean copperas, and let it stand one or two months, stirring it frequently, and pour off the part free from sediment for use.

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nut-galls? What are some of its properties? What useful substance does it form with the persalts of iron?

534. What is formed when solution of tannic acid is exposed to the air? Are there other organic acids?



when solution of tannic acid is exposed to the air, by the gradual absorption of oxygen, and by other means. It is a crystalline solid, soluble in hot water, and has an astringent and somewhat acid taste. With the bases it forms salts; none of which, however, are important.

There are other organic acids, which, however, our limits do not allow us to introduce.

### VEGETABLE ALKALIES.

535. The vegetable alkalies are a class of bodies found in various vegetable substances, which, like potash, ammonia, and other bases, unite with acids, forming salts. They all contain nitrogen; and most of them are but slightly soluble in water, and are exceedingly poisonous. In the plant, they are always in combination with some acid. A few only of the many substances belonging to this class can be here described.

536. *Morphia*, or *Morphine*— $C_{16}H_{19}NO_3$ .—This alkaline substance is an essential ingredient of *opium*, which is the dried juice of certain species of the poppy, cultivated largely in different parts of Asia. Incisions are made in the capsules at the proper time, and the milky juice that exudes is allowed to dry upon the plant. The substance is then carefully scraped off, and constitutes the opium of commerce. The several processes for extracting morphia from opium are not difficult, but are somewhat tedious and complicated. In the opium, it is combined with sulphuric and meconic (from *mecone*, poppy) acids, the latter of which is peculiar to this substance.

535. What are the vegetable alkalies?

536. In what is morphia found? How is opium procured from the poppy? With what acid is the morphia combined in the poppy? What are some of the properties of morphia?

Pure morphia is a crystalline solid, but slightly soluble in water, and of a bitter taste. It combines readily with acids, forming salts, the most important of which are the *sulphate*, *acetate*, and *hydrochlorate*. These salts are very soluble in water, and have an intensely bitter taste. They are extensively used in medicine.

537. *Narcotine*.— $C_{48}H_{24}NO_{16}$ .—Narcotine, or narcotina, is also contained in opium, from which it is separated by digesting the opium in ether. It has but a feeble power of neutralizing acids, and is therefore less alkaline in its character than morphia. Besides the above, several other alkaline substances are extracted from opium in very small quantity.

538. *Quinia*, or *Quinine*.— $C_{20}H_{12}NO_2$ .—Quinine is obtained only from the bark of certain species of a tree called *cinchona*, which grows chiefly in South America. In commerce it is called Peruvian bark, and is extensively used in medicine. Quinine is a crystalline solid, slightly soluble in water, and intensely bitter. It combines readily with acids, as the sulphuric and hydrochloric; and the salts formed are extensively used in medicine, especially in certain fevers.

539. *Cinchonia*, or *Cinchonine*.— $C_{20}H_{12}NO$ .—Cinchonia always accompanies quinia in Peruvian bark, and is obtained from it by a similar process. It differs in composition from quinia in containing a single atom less of oxygen; but in most properties, the two substances are much alike. Alone, it is but slightly soluble in water; but the salts it forms with acids dissolve more readily, and are used in medicine.

Several other alkaline substances are obtained from Peru-

537. How is narcotine separated from opium?

538. From what is quinia obtained? What is this bark called in commerce? What salts of quinia are used in medicine?

539. What other vegetable alkali is associated with quinia in

vian bark, but they possess little interest. These, as well as quinia and cinchonia, in the bark are in combination with a peculiar vegetable acid, which has been called the *kinic acid*.

540. *Strychnia*, or *Strychnine* ( $C_{14}H_{23}N_2O_4$ ) is a vegetable alkali obtained from *nux vomica*, and other plants. It is the poisonous principle of the famous *Upas*, of the island of Java, of which so many fables are told. It forms an extensive series of salts with the acids.

541. *Brucia* is a similar alkaline substance, obtained from the same source.

Other vegetable alkalies are *veratria*, from the *veratrum album*; *solania*, from several species of *solanum*; *conia*, from *conium maculatum*, &c.

542. *Theine*, and *Caffeine* ( $C_8H_{10}N_2O_2$ ), obtained from tea and coffee, appear to be the same substance. It is found also in the fruit of some other plants, and is contained in larger quantity in tea than in coffee. It is not certain that these articles, so extensively used among civilized nations, owe their peculiar properties to this principle.

## COLORING-MATTERS.

543. Infinite diversity exists in the colors of vegetable substances; but the prevailing tints are red, yellow, blue, and green, or mixtures of these colors. Coloring matter rarely or never occurs in an insulated state, but is always attached to some other principle, such as mucilaginous, extractive, farinaceous, or resinous substances, by which some

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Peruvian bark? What acid are these alkalies combined with in the bark?

540. From what is strichnia obtained?

541. What other vegetable alkalies are mentioned?

542. What is said of theine and caffeine?

543. What are the prevailing colors of vegetable substances?

of its properties, and particularly that of solubility, is greatly influenced.

The art of coloring consists in attaching the different coloring-matters to the fabrics to be colored. This is accomplished in various modes, as by adding some substance that forms an insoluble compound with the coloring-matter, or one that has the property of causing the coloring-matter to attach itself permanently to the fibre of the cloth. A substance used for this last purpose is called a *mordant*.

544. *Indigo, and Substances derived from it.*—Indigo is well known as an important blue coloring substance. It is derived from the juices of several American and Asiatic plants, which are soaked for a time in water, and the clear liquid, by standing, gradually becomes blue, and deposits the indigo as an insoluble powder.

545. The indigo of commerce is obtained in square cakes, of a deep blue color, and an earthy, and somewhat coppery aspect. It is always mixed with more or less foreign matter. Pure indigo ( $C_{16}H_8NO_2$ ) is quite insoluble in water and alcohol, but dissolves in heated sulphuric acid; and the solution is used in dyeing *Saxon blue*. At high temperatures, it is sublimed, and the vapor condenses on cold surfaces in fine crystals. Digested in water with lime and copperas, its blue color is destroyed, and a yellow liquid obtained, which, by standing, absorbs oxygen from the air, and the indigo is reproduced. Substances soaked in the yellow liquid become of a deep blue by exposure to the air. The finest indigo blues are produced by this mode.

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In what does the art of coloring consist? How is this accomplished? What is a mordant?

544. From what is indigo derived? What is the process of manufacturing it from the plants?

545. Is indigo soluble in water? What liquid dissolves it? How may its color be changed to yellow? What is the effect when this yellow is exposed to the air?

546. *Aniline* ( $C_{12}H_7N$ ) is an alkaline substance, formed by heating indigo with caustic potash, when the aniline distills over, and is condensed in a cool receiver. It is an oily liquid, which has the density of 1.028. Aniline forms numerous salts with the different acids. It is also found in the oil of coal-tar.

547. *Isatine* ( $C_{16}H_5NO_4$ ) is derived from indigo by heating it with dilute nitric acid. It is a crystalline solid, of an orange-red color, soluble in hot water and in alcohol. From this substance isatinic acid is derived, and several other compounds.

548. *Litmus* is a coloring substance, resembling indigo, obtained from several species of lichen. It is seen in small cubical masses, which are partially soluble in water, and the solution communicates a beautiful blue to substances immersed in it. This substance is much used in chemical investigations for detecting the presence of acids and bases; the former of which change its blue color to red, and the latter again restore the blue. It is a compound of several principles, as *lecanorine*, and *orcine*.

549. *Madder* is a red coloring substance, obtained from the roots of a plant called *rubia tinctorum*. It contains several principles, the most important of which is a red crystalline compound ( $C_{27}H_{12}O_{10}$ ) termed *alizarine*. The beautiful crimson called *Turkey-red* is produced by madder; which also, by different processes, is made to yield a yellow and a purple.

550. *Hæmatoxyline* is a substance obtained from log-

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546. How is aniline formed?

547. What is the method of preparing isatine? What is its color?

548. From what is litmus procured? What change is produced upon it by acids?

549. What is madder? What color is produced by it?

550. From what is hæmatoxyline procured?

wood, which, with iron-salts, produces black. It is contained in the black dyes used for hats and for broadcloth.

551. *Brezeline* is a crystalline solid, of an orange color, obtained from *Brazil-wood*, which is soluble in water and alcohol. With mordants, it gives a beautiful red. The same substance is contained in the African wood called *cam-wood*.

552. *Carmine* is a beautiful red coloring-matter, procured from the bodies of the *cochineal* insect, which feeds upon certain species of cactus.

553. *Quercitrine* is a yellow coloring-matter, contained in the bark of the *quercus tinctoria*, and probably in other vegetable substances used in coloring yellow. A fine yellow is also produced by the *turmeric root*, and by the root of the common barberry (*berberis vulgaris*). The leaves of the common gray birch (*betula lenta*), with the proper mordants, produce an excellent and permanent yellow, much used in some parts of New England.

## FATTY SUBSTANCES AND OILS.

### FATTY SUBSTANCES.

554. The fats and oils belong to the same general class, and are composed of the same elements, but in various proportions. The characteristic distinction between them seems to be that the fats are solid at ordinary temperatures, while the oils are liquid. They are all very combustible, and insoluble in water; and are found both in vegetable and

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551. From what is brezeline obtained?

552. What is carmine?

553. What is quercitrine? What other substances are used for dyeing yellow?

554. What is the essential distinction between fats and oils? What are some of their general properties?

animal bodies. Most of them are mixtures of several different substances, as will soon appear.

555. *Suet* is the fat obtained from the ox, sheep, goat, and other animals; which, when heated for a time, to separate the fat from the animal tissue, yields *tallow*. This is found to be chiefly a mixture of three principles; *margarine* (from *margarites*, pearl), *stearine* (from *stear*, tallow), and *oleine* (from *elaion*, oil); and each of these is composed, in part, of another principle, called, from its sweetish taste, *glycerine* (Greek, *glukus*, sweet). This last substance, *glycerine* ( $C_3H_5O_3$ ), is obtained from the fats and oils by heating them with a caustic alkali, and decomposing the compound by an acid. It is a liquid of specific gravity 1.26, which is soluble in water and alcohol. It unites with sulphuric acid, forming a coupled (504) acid, like the sulphovinic acid.

556. *Margarine* ( $C_{74}H_{74}O_{12}$ ) is a pearly white substance, which melts at  $118^\circ$ ; and is obtained from tallow by digesting it in hot ether; and the liquid portion being then poured off and evaporated, yields the margarine, mixed with oleine. This last substance is separated by pressing it between folds of bibulous paper. It is composed of *glycerine*, *margaric acid*, and the elements of water. By heating margarine with an alkali, the margaric acid combines with the alkali, forming a margarate of the base, and the *glycerine* is set free. The composition of margaric acid is  $C_{34}H_{34}O_4$ . It is a white pearly substance, not unlike spermaceti, which melts at about  $170^\circ$ .

557. *Stearine* ( $C_{142}H_{141}O_{17}$ ), which forms the chief con-

555. What is suet? What is tallow? Of what is tallow composed?

556. How is margarine obtained from tallow? What are some of its properties? Of what is it composed?

557. Describe stearine. Of what is it composed? How may

stituent of tallow, is a white crystalline solid, like spermaceti, and melts at about  $140^{\circ}$ . It is composed of glycerine, *stearic acid*, and the elements of water; and is obtained from mutton-suet by washing it thoroughly with ether, which separates the small quantity of margarine and oleine contained in the suet. It is insoluble in water, but dissolves in boiling alcohol, from which it crystalizes on cooling. *Stearic acid* ( $C_{18}H_{36}O_2$ ) is obtained from stearine by digesting it with an alkali, and decomposing the stearate formed by dilute hydrochloric acid. It is a white, tasteless, and inodorous substance, insoluble in water, but soluble in boiling alcohol. It melts at  $167^{\circ}$ , and solidifies at  $158^{\circ}$ . Heated in the open air, it burns like wax; and is the substance of which stearine candles are made. For this purpose, it is formed by digesting tallow or lard with lime-water, and decomposing the stearate of lime by dilute oil of vitriol, and then subjecting the mass to great pressure, to free it from the liquid matter contained in it.

558. *Oleine* ( $C_{94}H_{170}O_{15}$ ), the third substance mentioned (555) as contained in fats and oils, like stearine in the fats, constitutes the great mass of most of the fixed oils, and exists only in small quantity in the more solid fats. Oils are essentially oleine, holding more or less stearine and margarine in solution. Pure oleine is obtained by dissolving an oil in hot ether, and then exposing the solution to intense cold, by which the stearine and margarine are crystalized out. It is a compound of glycerine, oleic acid, and the elements of water. *Oleic acid* ( $C_{18}H_{34}O_2$ ) is procured from oleine by digesting it with potash, and decomposing with hydrochloric acid. At ordinary temperatures,

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stearic acid be obtained? Describe it. How is it prepared from tallow or lard for the manufacture of candles?

558. Of what does oleine constitute the chief ingredient? How is oleine obtained? What is oleic acid? Describe it.



it is a liquid lighter than water, and is without taste or odor. It remains liquid at low temperatures.

559. *Lard* is the fat of the hog, separated from the animal tissues. It is softer and more fusible than tallow, containing a larger proportion of oleine, and less stearine and margarine. The oleine obtained from it constitutes the *lard-oil* of commerce.

By the action of the acids, alkalies, and alcohol upon the above substances contained in the fats and oils, a long list of compounds is obtained, which cannot be here introduced.

560. *Butter* is an impure fat, obtained by a well-known process from the oily part of milk, called cream. It contains stearine, margarine, and oleine, besides several principles peculiar to itself, the chief of which is *butyrine*. This is a colorless oil, having the odor of melted butter, which becomes solid at  $32^{\circ}$ . By digesting butter with an alkali, decomposing with tartaric acid, and distilling, a volatile acid, the *butyric* ( $C_4H_7O_2$ ), is obtained mixed with other substances, from which it may be separated without much difficulty. Butyric acid may also be formed from sugar, by mixing with a solution of it a little curds of milk and powdered chalk, and allowing it to stand for a time in a place where it shall be kept at a temperature of about  $90^{\circ}$ .

561. *Bayberry tallow*, or *myrtle wax*, is a fat obtained from the fruit of the common bayberry (*myrica cerifera*). It is obtained from the berries by steeping them in hot water, and is found in other vegetables. Its composition is essentially the same as common tallow, but it contains other principles in small quantity.

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559. What is lard? What is lard oil?

560. What is butter? What are some of the principles it contains? How may butyric acid be obtained from it? How may this acid be also formed from sugar?

561. From what is bayberry tallow procured?

562. *Spermaceti*.—Spermaceti is a beautiful white substance, found mixed with oil in cavities of the heads of certain species of whales. The oil is separated from it by pressure; and the hard, white, crystalline substance thus obtained melts at about  $120^{\circ}$ , and may be sublimed unchanged in close vessels at about  $680^{\circ}$ . Spermaceti contains no glycerine; but in its place a peculiar principle called *ethal* ( $C_{22}H_{44}O_2$ ) is found, which may be separated, as a colorless, crystalline solid. Spermaceti contains in combination with ethal both margaric and oleic acids.

563. *Ethal*, in many of its properties, closely resembles the alcohols; and various bodies are derived from it similar to those derived from the alcohols.

564. *Bees'-wax* is obtained, as is well known, from honey-comb by heating it with water; the wax melts and swims upon the surface, while the impurities it contains are dissolved in the water, or settle to the bottom. It appears to be a compound of two principles, *cerine* and *myracine*, which may be separated by boiling alcohol. The latter substance is also contained in bayberry tallow. Common bees'-wax is of a yellow color, but is whitened by exposing it in thin layers to the action of the atmosphere and of light.

## OILS.

565. The oils constitute a very large class of bodies, which, as stated above, are generally liquid at common temperatures; but there is considerable difference among

562. What is spermaceti? What peculiar principle does it contain?

563. What group of bodies does ethal resemble in many of its properties?

564. What is bees'-wax? What two principles does it contain?

565. What is generally the state of the oils at ordinary tem-

them in this respect. They may conveniently be divided into the two classes of *fixed* and *volatile oils*; the former of which cannot be evaporated without decomposition, while the latter evaporate even at low temperatures. A drop of a fixed oil upon a piece of paper produces a permanent stain; by which means it may always be distinguished from a volatile oil, which will entirely evaporate. Some of them absorb oxygen from the air, and form a solid resinous substance, and are therefore called *drying-oils*. Such oils are suitable for painting, as, after they are spread upon the surface of a body, they absorb oxygen and form a resinous coating or film upon it, inclosing any coloring-matter that may have been mixed with the oil. *Printers' ink* is a preparation of some drying-oil and some coloring-matter, as lamp-black, vermilion, or Prussian blue.

566. *Fixed Oils*.—Most of the vegetable fixed oils are obtained from the seeds of plants, generally by grinding and then subjecting the mass to great pressure, aided by a slight heat.

567. *Linseed oil*, from the seeds of flax, is well known, being used almost universally by painters. Exposed to the air in thin films, as when spread upon the surface of wood, or other substance, it absorbs oxygen rapidly; and this tendency is increased by previous boiling, or by containing in it certain other substances, as litharge (oxide of lead); which, when thus used, are called dryers. When wool, flax, hemp and similar substances are saturated with this oil, and exposed to the air, the absorption of oxygen is

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peratures? Into what two classes may they be divided? Describe the difference between these classes. Why are some called drying oils? Of what is printers' ink made?

566. From what are most of the vegetable fixed oils obtained? By what means are they extracted?

567. From what is linseed oil procured? What use is made of it? What change takes place in it when exposed to the air?

sometimes so rapid\* as to cause spontaneous combustion by the heat developed.

568. *Walnut oil*, from the kernel of the common walnut, is also an oil that dries rapidly; but is inferior in this respect to the former.

569. *Hempseed oil*, *croton oil*, and *oil of poppy-seed*, possess the same character.

570. *Olive oil* is procured from the pulp of the olive, and is much used, under the name of *sweet oil*, as an article of food, and for other purposes. It is composed chiefly of oleine and margarine, the latter of which is present in considerable quantity; and therefore the oil congeals when moderately cooled. It is not a drying oil, but absorbs oxygen very slowly when exposed to the air.

571. *Palm oil*, usually so called, though it is not perfectly liquid at ordinary temperatures, is obtained from the fruit of certain African trees, and is imported largely into this country and in England for the manufacture of soaps. It is composed of oleine, a peculiar stearine, and *palmatine*, a substance analogous to margarine. *Palmitic acid* sustains the same relation to palmatine as the margaric acid to margarine, &c.

572. *Castor oil* is well known, as used in medicine. It is procured from the *castor bean*, which is the seed of the *ricinus communis*. It appears to contain several principles peculiar to itself, though its composition is analogous to that of other oils. It is soluble in its own volume of alcohol.

568. What is said of walnut oil?

569. What other oils are mentioned as possessing the same property?

570. What is sweet oil? What use is made of it?

571. What is said of palm oil? What is it composed of?

572. From what is castor oil obtained? What use is made of it?

X

573. *Spermaceti oil*, as it is called, is obtained from certain species of whale; and, like the various fish oils, appears to be composed of oleine, margarine, and stearine, in variable proportions. The same may be said of the other animal oils in general.

574. *Soaps.—Plasters.*—Frequent allusion has already been made to the action of the alkalies upon the fats and oils;—when these are boiled together, union takes place between them, and a well-known and very important substance is formed, called *soap*. The acids contained in the fat or oil, as the margarinic, stearic, oleic, &c., described above, combine with the alkalies, forming proper salts, which exist in the soap together with other substances.

All the soaps may be divided into the two kinds, hard and soft; the former of which are made with soda, and the latter with potash. They all contain a large proportion of water; which, however, exists in a different condition in the soda soaps from that in which it is contained in the soaps of potash.

Of the hard soaps there are two varieties, the white and the yellow;—the white is made entirely of soda and pure tallow, and the yellow of soda, with tallow, palm oil, and resin (common rosin).

Soft soaps are made entirely of potash and tallow or oil, and often other animal matters. For the coarser kinds, very impure fats are used without even separating them from the animal tissues in which they are contained.

575. The *lead-plaster*, or *diachylon*, used in medicine, is

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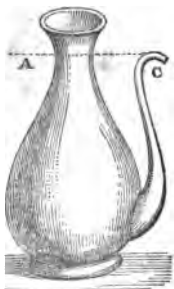
573. From what is spermaceti obtained?

574. What is the effect when an alkali is boiled with a fat or oil? What are the chemical changes that take place? What two kinds of soap are there? Which of these is made with soda, and which potash? What is the difference between the white and the yellow hard soaps?

575. How is lead-plaster, or diachylon, formed? How is its formation explained?

a kind of metallic soap, which is made by boiling olive oil and oxide of lead together, with a little water. The oleic and margaric acids contained in the oil unite with the oxide of lead, in the same manner as they combine with the alkalis (oxides of potassium and sodium) in the formation of soaps. There are two kinds of diachylon, the yellow and the brown; the former of which is made with litharge, and the latter with red lead; but their properties are essentially the same. Both are quite hard at ordinary temperatures, but melt with a moderate heat.

576. *Volatile, or Essential Oils.*—These are numerous, and are all of vegetable origin. Most of them are obtained from the leaves and flowers of plants; but some are found in the bark or fruits, or other part of the plant. They differ essentially in composition; some of them containing oxygen, and others being destitute of it, and a few of them containing sulphur. In general they are obtained by distilling the part of the plant containing them with water;—both the oil and the water pass over in vapor, and are condensed in the usual mode, and are afterwards separated by the oil rising to the surface. One only, the oil of winter-green, being heavier than water, sinks to the bottom. A vessel of the form figured in the margin answers well for separating all but the one last mentioned from the water with which they are distilled. It is first filled with water to the line A, and then the mixed liquids are poured into it in a small stream, the oil remaining at the surface while the water escapes at C. This, it is evident, may be



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576. From what are the essential oils obtained? Do these oils differ essentially in composition? What is the mode of distilling them? Describe the mode of separating the oil after distillation

continued until the vessel is nearly filled with the pure oil; or until, if more were added, the oil itself would begin to escape by the spout C.

Most of the essential oils consist of at least two principles; one of which is less fusible than the other, and may be separated by cold. Thus, by exposing oil of peppermint to severe cold, a solid not unlike camphor is crystalized out, and may be separated from the portion that remains liquid. These solids, sometimes called *stearoptens*, are different in the different oils; some being much more easily solidified than others. Their composition is also various; some being isomeric with the oil which yields them, and others, hydrates or oxides of the oils.

577. *Oil of turpentine* is procured, by distillation, from common turpentine, a substance which exudes from incisions made in the wood of several species of pine. It is a limpid colorless liquid, of specific gravity about 0.87, and boils at 315°. It is composed, when pure, solely of carbon and hydrogen, but absorbs oxygen from the atmosphere, and forms resin. It is frequently called *camphene*, and is used in lamps as a substitute for oil. When a current of dry hydrochloric acid gas is passed through it, a white solid is formed, resembling common camphor, and is called *artificial camphor*.

578. *Oil of lemons* is obtained from the peel of the fruit simply by pressure. It is lighter than water, and boils at 330°. It is isomeric with oil of turpentine; and, like that substance, also forms a white solid with hydrochloric acid.

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from the water. Of what two principles do most or all of the volatile oils consist? What is said of the oil of peppermint in this connection? Are the *stearoptens* of the different oils the same?

577. From what is oil of turpentine procured? Why is it often called *camphene*?

578. From what part of the fruit is the oil of lemons procured?

579. *Oil of bergamot*, which much resembles the last mentioned, is procured from a species of the lime.

580. *Oil of cinnamon* (526) is contained in the bark of several species of *laurus*, which grows chiefly in the East Indies; and is obtained by distilling the bark with water.

581. *Oil of peppermint* exists in the leaves and stem of the plant, from which it is separated by distillation with water. This oil is used in large quantities by confectioners; and in some of the western states the plant is extensively cultivated to be distilled for the oil. Dissolved in alcohol, it forms the well-known *essence of peppermint*. The other essences are prepared in the same manner, by dissolving a small portion of the oil in alcohol.

582. *Oil of roses* is obtained entirely from the flower by distilling with water. In consequence of the high price it bears, it is often adulterated largely with other oils. It is frequently called *otto*, or *attar of roses*.

583. *Oil of neroli* is an oil obtained in the same manner from orange flowers.

584. *Oil of mustard* is one of the few oils that contain sulphur. It is obtained from the mustard seeds by distillation with water, after the fixed oil has been expressed by the aid of a moderate heat.

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579. Oil of bergamot?

580. From what the oil of cinnamon?

581. In what part of the plant is the oil of peppermint contained?  
What is essence of peppermint?

582. From what part of the plant is the oil of roses procured?

583. What is oil of neroli?

584. What is said of the oil of mustard?



## RESINOUS AND BITUMINOUS SUBSTANCES.

## RESINS.

585. Several of the resins are closely allied to the essential or other oils. We have seen above that the drying-oils (565) and oil of turpentine (577), when exposed to the air, absorb oxygen and form resinous substances, which specially fits them for use in painting. The resins exist in the plants either pure or in combination with an essential oil. They are solid at ordinary temperatures, and by friction become negatively electrical. Most of them are soluble in alcohol, ether, and the essential oils, but are insoluble in water. They combine readily with the caustic alkalies (574), forming soapy compounds.

586. *Common resin*, or *rosin* (as it is called in commerce), is obtained from different species of pine, in which it exists combined with oil of turpentine. The substance called turpentine is obtained from the trunk of the tree by incisions made in it while growing; and this, by distillation (577), yields the oil of turpentine, the resin remaining behind in the boiler.

When the tree is felled, and the turpentine extracted by heat, it is partially decomposed, and acquires a dark color, and an offensive burnt odor, and is called *tar*. By heating tar so as to expel all the oil of turpentine contained in it, the common *pitch* of commerce is obtained.

587. *Lac*, or *gum lac*, as it is often called, is procured from a species of tree called *ficus*, by punctures made in the

585. To what are some of the resins closely allied? In what state do the resins exist in plants? In what are most of the resins soluble?

586. From what is rosin obtained? How is the turpentine extracted from the tree? How is tar obtained?

587. From what is lac obtained? In what is it soluble?

bark by insects. It is soluble in alcohol and heated oil of turpentine; and is used in the preparation of varnishes and sealing-wax.

588. *Copal* is the resin of a tree found in warm climates. It is much used in preparing copal varnish, and differs from other resins in being scarcely soluble either in alcohol or ether. Copal varnish is made by melting the resin cautiously in a close vessel, and then adding heated linseed oil and oil of turpentine. For most purposes it is preferred to all other varnishes.

*Mastic* and *sandarac* are resins much resembling lac in most of their properties.

589. *Amber* is always found as a fossil, but it appears to be the resin of some ancient tree that has become extinct. It is found on the shores of the Baltic sea, on the Yorkshire coast of England, and in some of the United States, as in New Jersey.

590. *Caoutchouc*, or *India-rubber*, is the product of several tropical trees. It is insoluble in alcohol, but dissolves in pure ether, and chloroform, and some of the essential oils. It is now made use of for various important purposes.

591. *Gutta-percha* is a substance nearly resembling caoutchouc in many of its properties, but at ordinary temperatures is much harder. At the temperature of boiling water it becomes quite soft, and may be worked into almost any desirable form. It is obtained from a large tree found, so far as is known, only in some parts of Southern Asia.

592. *Camphor*, though closely related, as we have seen

588. What is copal? How does it differ from the gums and most of the resins? How is copal varnish formed?

589. Where is amber found?

590. What is said of caoutchouc, or India-rubber?

591. What is gutta-percha? What are some of its properties?

592. To what is camphor closely related? Describe it. From

(576), to some of the volatile oils, is properly to be classed with the resins. It is a white solid, of a pleasant, aromatic odor; and is procured in the solid state from the *laurus camphora* of Japan. It is very soluble in alcohol, and may be sublimed without change in close vessels. Several of the essential oils, when exposed to severe cold, yield solids peculiar to themselves, which are considered camphors. *Borneo camphor* is a peculiar variety obtained from the island of Borneo. Its odor is different from that of ordinary camphor, and it is also heavier. It is highly prized by the Chinese and other eastern nations, and seldom is seen in this country.

## BITUMENS.

593. Several of the substances included under this head are obtained from the earth as natural productions, while others are procured by the destructive distillation of wood and other vegetable bodies.

594. *Naphtha*.—This substance exists in the earth in many countries, mixed with various impurities, and is found upon the surface of the water in springs and lakes. In its impure state it is called *petroleum*, from which the *naphtha* is obtained by distillation. It is a yellowish volatile liquid, of specific gravity 0.753. It may be obtained in small quantity by distilling bituminous coal. Petroleum is found in considerable abundance in some parts of Seneca Lake, in the state of New York, and called *Seneca oil*.

what is it obtained? What is said of some of the essential oils in this connection?

593. Where are most bituminous substances obtained?

594. In what is *naphtha* found? What is it called in the impure state in which it is found? How is the *naphtha* separated from petroleum? Describe *naphtha*.

595. *Asphaltum, or mineral pitch*, is a black, solid substance, obtained from the earth in various countries, and contains more or less naphtha. It melts with a moderate heat, and burns freely in the open air.

596. *Naphthaline*— $C_{10}H_8$ .—This is a solid substance obtained by distillation from coal-tar, which is a substance collected in the preparation of illuminating gas from bituminous coal. It is a white crystalline solid, which melts at  $136^\circ$ , and boils at about  $413^\circ$ . By the action of chlorine and bromine upon it, many peculiar and interesting compounds are formed, which cannot be here described.

597. *Paraffine* is procured by distilling wood-tar, and is also contained in petroleum. It is a solid lighter than water, and melts at about  $110^\circ$ . It received its name (*parum affinis*) from the circumstance that it manifests little affinity for other substances.

598. *Eupione* ( $C_8H_6$ ) is a liquid substance obtained also from wood-tar. It boils at  $340^\circ$ , and has a density of 0.655 only.

599. *Creasote, or Kreosote*— $C_{14}H_{10}O_2$ .—This substance is procured from crude pyroligneous acid by a complicated process. It is a colorless liquid, a little heavier than water, which boils at about  $397^\circ$ . It has a most disagreeable odor of smoke, and a pungent burning taste. One of its most important properties is its power of preserving meat and other animal substances from putrefaction; from which it derives its name (*kreas*, flesh, and *sozo*, to preserve). It is this substance which gives to smoked meat and fish their peculiar flavour, and at the same time preserves them from

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595. What is asphaltum or mineral pitch?

596. What is naphthaline? What are some of its properties?

597. How is paraffine procured? Describe it.

598. What is eupione? Describe it.

599. How is creasote procured? What are some of its proper-

tainting. It is used in medicine, but when taken internally in any quantity it is highly poisonous.

#### CYANOGEN AND ITS COMPOUNDS.

600. Cyanogen ( $C_2N$ ) has already (247) been in part described. It is usually prepared by heating bicyanide of mercury. At ordinary temperatures it is gaseous, but may easily be converted into a liquid by the moderate pressure of 3.6 atmospheres.

This may be done as follows: Let a small quantity of cyanide of silver be introduced into a strong glass tube, bent, as in the figure, and hermetically sealed. It



is then to be held horizontally, and the heat of a lamp applied at the extremity *a*, containing the cyanide of silver. The other extremity, *b*, is to be kept cool; and in a short time the liquid cyanogen will be seen to collect in it.

Cyanogen is one of the most important of the compound radicals (455), and by union with other substances forms a great variety of interesting compounds.

601. *Hydrocyanic, or Prussic, Acid* —  $C_2N_3H$ . — This compound is contained in the water distilled from the leaves and blossoms of the peach and other stone fruits, and gives to them their flavour. It may easily be procured by decomposing cyanide of mercury by sulphuretted hydrogen, and collecting the gas in a cold receiver.

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ties? What is said to be its most striking property? For what purposes is it used?

600. How is cyanogen usually prepared? What is said of it as a compound radical?

601. In what is hydrocyanic acid contained? How may it be procured? What are some of its properties? What is said of its poisonous character?

Pure hydrocyanic acid is a colorless liquid, which has a density of about 0.70, and boils at  $80^{\circ}$ . In the open air it evaporates rapidly; and, by the cold produced, a portion of it is frozen. Its odor is strong and pungent, resembling that of peach-blossoms. It mixes readily both with water and alcohol; and is one of the most terrible poisons known to man. A single drop of it placed upon the tongue of a dog causes death in a few seconds. It is considerably used in medicine; but for this purpose it is largely diluted with water. When long kept, especially if exposed to the action of light, it is liable to spontaneous decomposition.

602. *Amygdaline* ( $C_{20}H_{27}NO_{11}$ ) is a principle which is contained in peach-kernels, in bitter almonds, and other similar fruits. It is a crystalline powder, and is soluble in water and alcohol. By boiling it with baryta, *amygdalic acid* is formed; which at once enters into combination with the baryta.

603. *Synaptase*, or *emulsine*, is a yellowish-white solid, obtained from the kernel of sweet almonds, the composition of which has not been fully determined. When a mixture of amygdaline and emulsine is made with water, a peculiar and complicated reaction takes place, which results in the production of bitter-almond oil, hydrocyanic acid, and grape-sugar.

604. *Cyanide of Potassium*— $K_2C_2N$ .—This compound is formed by saturating an alcoholic solution of potash by hydrocyanic acid, by heating potash with animal matter, or by igniting the yellow prussiate of potash in a close crucible. It is a white solid, very soluble in water, and

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602. What is amygdaline?

603. What is synaptase or emulsine? What are produced when a mixture of amygdaline and emulsine is made with water?

604. How is cyanide of potassium formed? For what is it used?

deliquescent in the air. It is much used in the electrotype process.

605. *Cyanide of Mercury*— $\text{Hg}_2\text{C}_2\text{N}_2$ .—Cyanide of mercury is easily prepared by dissolving oxide of mercury in hydrocyanic acid, and by other means. It is used in preparing cyanogen. *Cyanide of silver*, prepared by mixing hydrocyanic acid with a solution of any salt of silver, is used for the same purpose. There are numerous other cyanides of the metals.

606. *Compounds of Cyanogen and Oxygen*.—Cyanogen and oxygen combine to form three acids, which are isomeric, but very distinct in their properties. They are the *cyanic* ( $\text{C}_2\text{NO} + \text{HO}$ ), the *fulminic* ( $\text{C}_4\text{N}_2\text{O}_2 + 2\text{HO}$ ), and the *cyanuric* ( $\text{C}_4\text{N}_2\text{O}_3 + 3\text{HO}$ ); each of which combines with bases, forming salts.

607. *Cyanates*.—Cyanate of potash is prepared by heating the yellow prussiate of potash (soon to be described) with peroxide of manganese, and digesting the mass in alcohol. It is a white crystalline solid. *Cyanate of ammonia*, or *urea*, is formed by bringing together hydrocyanic acid gas and ammonia, and by the action of cyanate of potash upon sulphate of ammonia. It is also contained in the urine of animals, and is therefore called urea. It is an interesting substance, as being the first decidedly organic compound (451) which was produced artificially. It is a transparent, crystalline solid, with little odor, and very soluble in water.

605. How is cyanide of mercury prepared? What use is made of cyanide of silver? Are there other metallic cyanides?

606. How many acids are formed by the union of cyanogen and oxygen? What is said of their relation to each other? What are their names?

607. How is cyanate of potash prepared? How is cyanate of ammonia or urea formed? For what is this substance particularly interesting?

608. *Fulminates*.—The fulminates of mercury and silver are the only ones of importance. *Fulminate of mercury* is prepared by dissolving 200 grains of mercury in an ounce of strong nitric acid by the aid of heat, and when cold, pouring into it about 4 ounces, by measure, of alcohol. The mixture should be contained in a large glass or earthen vessel, and a little heat applied if the action does not commence in a few minutes after adding the alcohol. When the action has once commenced, it goes on violently, without the further aid of heat, attended by the evolution of white fumes and the deposition of the solid fulminate in question in small crystals. When washed and dried, it explodes with slight friction, or by a blow, or by the contact of strong nitric or sulphuric acid. Mixed with nitre, it forms the preparation contained in percussion caps. *Fulminate of silver* is prepared very nearly in the same manner as the above. A dime is to be dissolved in about 2 ounces of common nitric acid, and the solution diluted with 2 ounces of rain-water, and then 2 ounces of alcohol added, and the whole mixed well by shaking. By application of heat, rapid ebullition will soon commence, when the heat should be removed; and the fulminate will be gradually deposited, and should be immediately washed and dried. It is a beautiful white solid, and should be handled with the utmost care, as it explodes most violently, even when damp, by the slightest friction, or by the mere contact of sulphuric acid. Both of the above substances, as well as the acid supposed to be contained in them, receive their names from their explosive properties.

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608. What fulminates are mentioned? How is fulminate of mercury prepared? What peculiar property has this substance from which the name is derived? What use is made of it? Describe the mode of preparing fulminate of silver. What is said of its tendency to explode?



**609. Double Cyanides.**—Several of the cyanides of different bases frequently combine, forming important compounds of great use in the arts.

*Ferrocyanide of potassium*, the *prussiate of potash* of commerce, is prepared on a large scale by igniting potash and iron-filings with animal matter, as old leather, woollen rags, and the horns and hoofs of animals, by which cyanide of potassium is formed, and oxide of iron. The mass is then digested in water moderately heated, and, by the action of the cyanide of potassium upon the oxide of iron present, the ferrocyanide is produced, and crystalizes from the solution. The crystals are of a beautiful lemon-yellow color, and are very soluble in water, but insoluble in alcohol. This substance contains the elements of two equivalents of cyanide of potassium, one equivalent of cyanide of iron, and three of water ( $2\text{KC}_2\text{N} + \text{FeC}_2\text{N} + 3\text{HO}$ ); but we cannot affirm that this is the mode in which they are really combined. Prussiate of potash is much used in the arts, and may always be distinguished by its striking a deep blue when mixed in solution with sulphate of iron.

**610. Prussian blue**, so extensively used as a blue paint, is formed by mixing in solution prussiate of potash and a salt of the peroxide of iron. Its composition is very complex. It is insoluble in water, but is decomposed by alkaline solutions.

609. Do the cyanides sometimes combine with each other? What is the composition of Prussiate of potash? How is it prepared on a large scale? What are some of its properties? How may it be always known?

610. What use is made of Prussian blue? How is it prepared?

SEVERAL SUBSTANCES COMMON BOTH TO THE  
VEGETABLE AND ANIMAL KINGDOMS.

611. It has been the usual practice to treat of animal and vegetable substances separately; but, as we shall see, there are many substances common to both classes of bodies, and therefore no attempt at such distinction is here made. So the processes of nutrition and respiration in animals and plants, though in many respects very different, still have so many points of resemblance that we prefer, in this work, to treat of them together.

612. *Albumen*.—This substance constitutes the white of eggs, and is contained in the blood and other parts of animals. It is soluble in cold water, but coagulates and becomes insoluble if heated to about  $158^{\circ}$ . It is precipitated from its solution by acids or solutions of the salts. *Vegetable albumen* is contained in the different kinds of grain; in various roots, as beets, turnips, &c., and in many kinds of wood. Its composition appears to be the same as that of animal albumen.

613. *Fibrine*.—Fibrine is contained in the blood, and constitutes the basis of the muscles of animals. Separated from other substances, it is a white, inodorous solid, insoluble in water or alcohol. It appears to be composed of elongated globules, which adhere together and give it a fibrous structure. Fibrine is soluble in dilute hydrochloric acid, and in solutions of the caustic alkalies.

611. Are there many substances common both to the vegetable and animal kingdoms? Are the processes of nutrition and respiration similar in plants and animals?

612. In what is albumen found? What is the effect of heat upon it? What is vegetable albumen? In what is it found?

613. In what is fibrine contained? What are some of its properties when separated from other substances? Of what does it appear to be composed? In what is fibrine soluble? Is it found in vegetables? How may it be obtained from wheat flour.

This substance is also found in vegetable bodies. When paste made of wheat flour is washed for a length of time with pure water, to separate the starch, a soft, tenacious substance is obtained; which has been called *gluten*, but is now found to be composed chiefly of a substance identical with fibrine, and is therefore called *vegetable fibrine*.

614. *Caseine*.—This compound constitutes the chief part of the curd of milk, and of course is the basis of cheese. When separated from the other substances contained in milk, and dried, it is an insipid, yellowish substance, like gum. It is soluble in water containing free alkali, and is not coagulated by heat, like albumen. It is, however, coagulated by acid, and by *rennet*, a liquid formed by digesting in water the interior coat of the stomach of a calf. Like albumen and fibrine, caseine also has its representative in the vegetable kingdom. This is obtained from peas, beans, and similar vegetables, and has been called *legumine*, but is now found to have the same composition as caseine.

615. The three substances above described, though entirely distinct in many of their properties, appear to have essentially the same composition, except that there is a little difference in the proportion of sulphur present. When any one of them is dissolved in an alkaline solution, and precipitated by an acid, a white, tasteless, insoluble substance is obtained, called *proteine*, which appears to serve as their basis. Besides *proteine* they also contain a small proportion of sulphur, as above intimated; and albumen and fibrine contain a little phosphorus. Albumen, fibrine, and caseine, because of their containing *proteine*, are sometimes, by way

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614. Of what does caseine constitute the chief part? Is it coagulated by heat? How is it affected by a free acid, or by rennet? Is caseine found in vegetables?

615. What is said of the composition of the three substances last mentioned? What is *proteine*?

of distinction, called *the proteine compounds*. They compose the chief part of the animal tissues, and are contained in several of the liquids of the animal system.

Proteine enters also into the composition of the hair and nails and horns of animals. Its composition is  $C_{40}H_{31}N_5O_{12}$ .

616. *Gelatine*, in a dry state, constitutes the glue of commerce. It exists abundantly in many parts of animals, as the skin, cartilages, membranes, &c.; from which it is separated by the action of boiling water; and the solution, on cooling, forms a tenacious jelly. *Isinglass* is a variety of gelatine obtained from fishes.

Gelatine may always be known by its forming a solid compound with tannic acid, called *leather*, which may be preserved in a dry state for any length of time, and is less liable to decay than almost any other substance of animal origin. Leather is usually formed by subjecting the skins of animals for some time to an infusion of bark, which contains a large proportion of tannic acid; and the chief chemical change which takes place is believed to consist in a union of this acid with the gelatine of the skin. This is the common leather of which shoes are made; other varieties of this useful manufacture are prepared by different modes. Glove-leather, for instance, is prepared by impregnating the skin, after having been deprived of all its fatty matter by soaking in a weak alkali, with solution of common salt and alum, from which chloride of aluminum is formed, and unites with the gelatine of the skin.

617. By boiling gelatine with dilute sulphuric acid, and precipitating the acid with chalk, a sweet crystalline compound is obtained called *glycocoll* (*glukus*, sweet, and *kolla*, glue), or *gelatine sugar*.

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616. What is glue? From what is it procured? How may gelatine always be known? How is leather formed?

617. How is glycocoll formed?

VARIOUS SUBSTANCES, MOSTLY OF ANIMAL  
ORIGIN.

618. *The Blood*.—The blood of different animals differs greatly in its appearance and properties. That of man and of the mammalia in general, is a slightly viscid liquid, of a dark purple color in the veins, but of a bright scarlet in the arteries. Either kind, after being drawn from the system, soon coagulates, and settles gradually into two portions, the *coagulum*, which is solid, and the *serum*, which is a yellowish liquid. The coagulum is composed chiefly of fibrine, mixed with globules of different sizes and forms in different animals, and containing the coloring matter, called *hematine*, or *hematosine*. In the blood of man, these globules, or discs, are about  $\frac{1}{4000}$ th of an inch in diameter. Iron, which constitutes about 6 or 7 per cent. of the hematine, seems to be an essential ingredient of blood, but its precise use cannot be explained. The *serum* of the blood has a density of about 1.03, and is chiefly a solution of albumen in water, with traces of alkaline and earthy salts. There are also contained in the blood, in small quantity, globules of fatty substance.

The coagulation of the blood consists essentially in the agglutination of the fibrine it contains; but perhaps some change also takes place in its other ingredients. The time required for this change varies considerably, and depends much upon temperature, being much more rapid in warm than in cold weather. It seems, also, to be influenced by the pressure of the atmosphere, as it takes place more rapidly

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618. Is the blood of all animals the same in appearance and composition? What is said of the blood in man and in the mammalia generally? What change soon takes place in the blood after being drawn from the system? What is the coagulum chiefly composed of? What is the serum composed of? In what does the coagulation of the blood consist? What substances are

in the open air than in a close bottle; but, on the other hand, the coagulation is rendered more rapid by placing the blood under an exhausted receiver.

Some substances prevent the coagulation of blood. This effect is produced by a saturated solution of chloride of sodium, hydrochlorate of ammonia, nitre, and a solution of potassa. The coagulation, on the contrary, is promoted by alum and the sulphates of the oxides of zinc and copper. The blood of persons who have died a sudden violent death by some kinds of poison, or from mental emotion, is usually found in a fluid state. Lightning is said to have a similar effect; but the point seems not to be entirely settled.

The cause of the coagulation of the blood has been the subject of much speculation among physiologists, and is as much a question at the present time as it ever was. The reason why the blood retains its fluidity, coursing its way through the various minute ramifications of the system, during life, but immediately coagulates when the vital principle has fled, yet remains one of the profound mysteries of nature.

All we can say is, the blood, whilst in connection with the living animal, participates in its life, and in consequence of it, retains its fluidity; but deprived of this vitality, it yields at once to other unknown influences which produce this effect.

The blood, as is well known, is constantly circulating through the system;—from the heart through the system and back to the heart, and then from the heart through the lungs and back a second time to the heart, to be again sent its former round through the system. While in the lungs, it is separated from the air in the air-cells only by a thin membrane, through which the air permeates; and it is here

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mentioned as preventing the coagulation of the blood? Is the cause of its coagulation known? Is the blood constantly circulating through the system? Describe its course. What change is

that the purple color of the venous blood is changed to scarlet, the color it retains while passing through the arteries, as will be shown more fully when we come to speak of respiration.

The blood may be diseased either by the excess or deficiency of one or more of its proper constituents, or from the presence of substances which are foreign to it. In acute inflammatory diseases, there is often a great increase in the quantity of fibrine; while in other diseases, as chlorosis, the fibrine is unaffected, but the albumen of the serum is diminished. In diabetes mellitus, traces of sugar are found in the blood, especially after meals.

One familiar instance of diseased blood is jaundice, when bile enters the circulation and is distributed to every organized part of the body. Though the presence of bile in the blood during jaundice has been detected, yet its passage into the circulating mass appears so rapidly succeeded by its exit, that its detection in the blood itself is generally difficult. Urea has also been detected sometimes in very large quantity: it appears to be constantly present in the blood, whenever the secretion of urine is suppressed.

619. *The Sap* of plants performs in them the same functions as are performed by the blood of animals; both serve to receive and distribute to the various parts of the organism the materials required for their growth and nourishment; and in both important chemical changes are constantly taking place, as will be seen more fully hereafter.

620. *Milk*.—This is a fluid secreted by the female of many animals for the nourishment of their young. It is of

produced in the blood in the lungs? May the blood be diseased? What instance of diseased blood is mentioned?

619. What office is performed by the sap in plants?

620. What are some of the properties of milk? What is it composed of? What acid is formed in milk by standing for a time at an elevated temperature?

a white color, and contains some twelve or thirteen per cent. of solid matter, the rest being liquid. It is not changed by heat, but is readily coagulated by all acids and by rennet, a substance which is obtained by digesting in water the lining membrane of a calf's stomach. It consists of water, caseine, milk-sugar, small quantities of several salts, and butter. This last substance is separated from it by the process of churning, and cheese consists mostly of the caseine contained in the milk.

When milk is allowed to stand some hours, at a temperature of between  $60^{\circ}$  and  $70^{\circ}$ , it sours; and, on examination, a peculiar acid is found in it called *lactic acid*, the composition of which is  $C_6H_8O_6$ . When highly concentrated, it is a thick, colorless liquid, of specific gravity 1.21, and has a very sour taste. It is soluble in alcohol and water, but cannot be crystalized.

621. Lactic acid may also be formed from sugar by mixing with it in solution some curds from milk, and some chalk to neutralize any free acid that may form, and allowing it to stand for some time at a temperature of about  $80^{\circ}$ . The chemical change that takes place appears to be very simple, as an atom of grape-sugar contains exactly the ingredients of two atoms of lactic acid. Thus,  $C_{12}H_{12}O_{12} = 2(C_6H_6O_6)$ .

Lactic acid is also formed when the juices of beets, carrots, &c., are allowed to ferment at high temperatures. At the same time a viscid, slimy substance is formed, from which circumstance this has been termed the *viscous fermentation*.

When lactic acid combines with bases, it gives up one equivalent of water, or its equivalent, as we have seen in other cases (482). None of the lactates are important.

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621. By what mode may lactic acid be formed from sugar? May milk be made to undergo the vinous fermentation?



When lactic acid is heated to near  $500^{\circ}$ , it is decomposed, and a substance which has been called *lactide* is sublimed, having the composition  $C_6H_4O_4$ .

Milk may also be made to undergo the vinous or alcoholic fermentation. For this purpose it is exposed for some hours to a temperature of about  $100^{\circ}$ ; and the alcohol, which, no doubt, is formed from the milk-sugar it contains, may subsequently be distilled from it. It has long been known that some barbarous nations are accustomed to prepare an intoxicating drink from milk by some fermenting process.

622. *The Gastric Juice*.—This liquid, which is secreted from the coats of the stomach, is slightly saline and acid, and serves to dissolve the substances taken as food. It contains a peculiar substance called *pepsine*; to which, and the free acid in it, its great solvent power is to be attributed. This property remains after it has been taken from the stomach, provided its temperature is kept at about  $98^{\circ}$  (the natural temperature of the system); but it is destroyed by a boiling heat, or by neutralizing the free acid it contains.

623. *The saliva* is a slightly viscid liquid, secreted by the glands of the mouth; and being mixed with the food in the act of mastication, it is supposed to aid in its digestion. It contains saline matter, as common salt, and phosphate of lime.

624. *The bile* is a greenish-yellow liquid secreted by the liver. It is bitter and nauseous to the taste, and contains a variety of substances, which cannot be here described. The bile is collected in the gall-bladder, and is conveyed

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622. From what is the gastric juice secreted? What purpose does it serve?

623. What is the saliva? What does it contain?

624. By what organ is the bile secreted? What is said of its taste? What purpose does it serve?

by a small duct, and mixed with the food immediately after it leaves the stomach, producing some important changes in it, by which it is fitted to perform its proper office in nourishing the system.

625. *The Pancreatic Juice*, a liquid secreted by the pancreas, not unlike the saliva in appearance, is also mixed with the partially-digested food at the same time with the bile, but the specific part it serves is involved in obscurity.

626. *The urine* is a yellowish liquid, secreted by the kidneys, by which various substances are separated from the blood when no longer needed. It is a little heavier than water, and contains in solution a small portion of urea (607) and several different salts, as well as a little free acid, from which it acquires an acid reaction. A little mucus is also usually present, derived from the urinary passages; and in consequence of this it putrefies if kept for a time at a summer temperature.

The urine of birds, insects, and reptiles, is solid, and consists chiefly of urate of ammonia. *Guano*, which has been so largely imported within a few years, to be used as a manure, is composed chiefly of the urine and other excrements of birds, which have been collecting for ages in the places where they are found. It is imported chiefly, if not entirely, from islands on the coast of Africa, and the west coast of South America.

Sometimes the composition of the urine in man and other animals becomes such, from the influence of disease, that a solid matter is deposited in the bladder, as a kind of gravel, or in large rounded masses, called *calculi*.

627. *The Bones*.—The earthy part of the bones of ani-

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625. What is the pancreatic juice?

626. By what organs is the urine secreted? What substances does it contain? What does the urine of birds and insects consist of? What is guano?

mals is composed chiefly of phosphate of lime, mixed with a little carbonate of the same earth, the whole being enveloped in a tissue of cartilage, of which gelatine is the chief ingredient. This earthy matter and the organic tissue may easily be separated from each other. To separate the solid or earthy matter, it is only necessary to digest the bone for a time in dilute hydrochloric acid, in which both the phosphate and carbonate of lime are soluble, so that they will be entirely removed, leaving the cartilage soft and flexible, but retaining perfectly the form of the bone. The cartilage may be removed by heating the bone some time in the open air, so as to burn away all the organic matter; or by digesting it in solution of an alkali, or in water at a high temperature under pressure. In some cases of disease, as rickets, to which children and youth are chiefly liable, there is a deficiency of earthy matter in the bones; and they are, in consequence, weak and incapable of affording the necessary support to the system.

628. *The teeth* have essentially the same composition as the bones except that they contain less cartilage.

#### CHEMICAL PHENOMENA OF RESPIRATION.

629. *Respiration of Animals.*—All organized bodies require constantly the presence of atmospheric air for the proper performance of their various functions, and their continued existence in the living state. All the larger land-animals are provided with lungs, in which, by the action of

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627. What is the earthy part of bones composed of? What serves to envelope this earthy matter? How may the earthy matter be removed without destroying the cartilage? How may the cartilage be separated from the earthy matter?

628. What are the teeth composed of?

629. Do all organized beings constantly require the presence of air? How is this air supplied to the lungs of the larger animals?

certain muscles, air is constantly inhaled and again expelled, and thus a continued circulation is kept up; but in some of the smaller ones, as insects, the breathing is by tubes called trachea, or is performed by the whole surface of their bodies. In fishes, certain organs, called gills, perform the office of lungs, and the air that is breathed is first absorbed by the water, and from this imparted to the animal. In every case the process by which the air is made to perform its office upon the living being is called *respiration*.

The important chemical changes that attend the respiration of animals are, the constant absorption of oxygen, and the formation and evolution of carbonic acid. To show the presence of carbonic acid in the air expelled from the lungs, it is only necessary to apply a small tube to the mouth, and blow, a few seconds, into some recently-prepared lime-water;—the carbonic acid in the air from the lungs will unite with the lime, forming carbonate of lime, which is insoluble in water, and is therefore precipitated, giving the solution a milkiness. It is true there is a little carbonic acid in the air before it is taken into the lungs; but while there the quantity is very considerably increased. This is shown satisfactorily by blowing in the same manner by a hand-bellows into another portion of lime-water, when it will be found that a much longer time will be required to produce the milkiness alluded to.

The blood in the larger animals is of two kinds, and is contained in two sets of vessels, the arteries and veins; the former of which convey it from the heart to the extremities,

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How do fishes breathe? What important chemical changes attend the respiration of animals? How may the presence of carbonic acid in the air expelled from the lungs be shown? What two kinds of blood are there in the larger animals? In what two sets of vessels is it contained? What difference is there in the color in the two kinds of arterial and venous blood? How is the change from the venous to the arterial state effected? How is the

and the latter serve to return it. The two kinds of blood are therefore called *arterial* and *venous* blood. Now, in the living body these two kinds of blood, as is well known, differ remarkably in their color; the latter is of a dark purple, but the former of a bright vermilion color. The change from the venous to the arterial state is effected in the living animal during the passage of the blood through the capillary vessels of the lungs, where it is exposed to the action of an extensive surface of atmospheric air, through the thin membranes which separate these from the air-vessels (618); and the arterial blood, in traversing the capillary system of the body, imparting nourishment to it, gradually assumes the dark-colored condition in which it is returned to the heart by the veins. The same change is produced when venous blood, just taken from the system, is brought in contact with atmospheric air, and is attended with the evolution of carbonic acid gas. It takes place more speedily when air is agitated with blood; it is still more rapid when pure oxygen is substituted for atmospheric air; and it does not occur at all when oxygen is entirely excluded. The quantity of carbonic acid developed very exactly corresponds with that of the oxygen which disappears.

There has been some difference of opinion in regard to the mode in which the carbonic acid is produced in the system; but it is now very well ascertained that the oxygen of the air in the lungs is absorbed by the blood, and carried by the circulation to every part of the body, where it combines with the carbon which is present in excess, producing the carbonic acid that is thrown off in the lungs. It is found, by examination, that both arterial and venous blood hold in solution quantities of oxygen, nitrogen, and carbonic

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oxygen of the air distributed over every part of the body? Does the air actually come in contact with the blood in the lungs? How then does the oxygen mix with the blood? Will the quantity

acid; but in arterial blood the quantity of oxygen is much greater in proportion to the carbonic acid than in venous blood, while the quantity of nitrogen is the same in both.

Formerly it was not known how the air is able to act upon the blood in the lungs, inasmuch as the air-cells and those containing the blood are separated from each other by membranes; but it is now fully settled that animal and other membranes are permeable by the different gases.

The quantity of oxygen withdrawn from the atmosphere, and of carbonic acid disengaged, is variable in different individuals, and in the same individual at different times, depending very much upon the state of the system. In a state of health, any thing that accelerates the respiration increases the amount of oxygen absorbed, and the quantity of carbonic acid exhaled; but in certain cases of disease, as in inflammatory fevers, though the respiration may be very rapid, little oxygen is withdrawn from the air, and the venous blood is found to be very florid.

630. *Animal Heat*.—It has long been known that there is a close connection between the function of respiration and the development of heat in the animal system.

Thus, in all animals whose respiratory organs are small and imperfect, and which, therefore, consume but a comparatively minute quantity of oxygen, and generate little carbonic acid, the temperature of the blood varies with that of the medium in which they live. In warm-blooded animals, on the contrary, in which the respiratory apparatus is larger, and the chemical changes more complicated, the temperature is almost uniform; and those have the highest temperature

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of oxygen inhaled, and that of carbonic acid expelled, always be the same?

630. What is said of the temperature of animals whose respiratory organs are small? What is said of the respiratory organs

whose lungs, in proportion to the size of their bodies, are largest, and which consume the greatest quantity of oxygen. The temperature of the same animal at different times is connected with the state of the respiration. When the blood circulates sluggishly, and the temperature is low, the quantity of oxygen consumed is comparatively small; but, on the contrary, a large quantity of that gas disappears when the circulation is brisk and the power of generating heat energetic. It has also been observed, that when an animal is placed in a very warm atmosphere, so as to require little heat to be generated within his own body, the consumption of oxygen is unusually small.

Although it is well known that the animal heat is connected with the respiration, as above shown, still it has not been found possible to determine the exact mode in which the heat is generated. It is however ascertained, as we shall see more fully by and by, that a large proportion of the food of all warm-blooded animals is expended in preserving the temperature of the system, while the remainder goes to supply the constant waste of the various tissues.

631. *Respiration of Plants.*—Plants, like animals, require the presence of air for their existence in a healthy state, and a kind of respiration takes place; but their action upon the air is altogether different from that of animals, and is performed chiefly, if not entirely, by means of their leaves. Animals, we have seen, constantly absorb oxygen from the air, which is required in the healthy action of the system, while carbonic acid, which is formed in the system in ex-

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of warm-blooded animals? Is the temperature of the same animal at different times dependent upon respiration? Does an animal respire less oxygen when in a warm atmosphere than in a cold one? Is a portion of the food of warm-blooded animals expended in preserving their elevated temperature?

631. Do plants, like animals, require the constant presence of air? What organs of plants correspond to the lungs of animals?

cess, is constantly given off to the air; on the other hand, plants, by the action of their leaves, at least while under the influence of light (207), are ever absorbing carbonic acid, the carbon of which is retained, while the oxygen is supplied to the air. When light is absent, it is said a reverse action takes place to a limited extent.

It is here, no doubt, that we are to look for the beautiful provision of nature, by which the necessary supply of oxygen is kept up, notwithstanding the constant expenditure in the processes of respiration and combustion. The absolute quantity of oxygen in the air is very great (223), but in a long course of ages it would necessarily be diminished sensibly, and the proportion of carbonic acid also sensibly increased, but for this or some similar arrangement for the preservation of the proper balance of the system.

#### CHEMICAL PHENOMENA OF THE NUTRITION OF ANIMALS AND PLANTS.

632. *Nutrition of Animals*—The matter of which the bodies of animals are composed is constantly changing and passing away, and requires to be renewed. This is done by the process of nutrition.

Some animals live entirely upon animal, and others upon vegetable food, or a mixture of the two kinds;—and the particular kind of food selected by each species seems especially adapted to it;—but it is now known that, chemically,

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What gas is absorbed from the air by the leaves of plants? Is the influence of light necessary to produce this result? What becomes of the carbonic acid thus absorbed? What important effect is thus produced by plants upon the atmosphere? Is the proportion of oxygen in the air always the same?

632. How is the constant waste in the animal system supplied? What is said of the food of different animals? What are all the



there is less difference between substances of animal and those of vegetable origin than was formerly supposed. All the different kinds of food used by animals consist essentially of the proteine compounds (615), gelatine, starch, sugar, and fatty and oily substances. Besides these, the graminivora devour large quantities of woody fibre, a part of which, being closely allied in composition to sugar and starch, is probably appropriated to the support of the animal. These substances may evidently be divided into the two classes of nitrogenized and non-nitrogenized; the former including the proteine compounds and gelatine, and the latter, starch, sugar, and the fats and oils;—and these two kinds of food, it is very well ascertained, serve very distinct purposes in the animal economy, the nitrogenized substances going to supply the waste in the animal tissues, and the non-nitrogenized being entirely consumed in supporting respiration and keeping up the animal heat.

We have seen above that a constant supply of oxygen is required to preserve the health and even the life of the animal system, and that the absorption of the oxygen is always attended by the evolution of carbonic acid and water. Now, these last substances are, without question, formed by the union of the carbon and hydrogen of the food with the oxygen received into the system in the act of respiration. And this carbon and hydrogen, we have good reason to believe, is furnished chiefly, if not entirely, by the non-nitrogenized food, mentioned above, which may therefore be called the *respiratory food*; while the nitrogenized sub-

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different kinds of food essentially composed of? Into what two classes may articles of food be divided? What is said of the different purposes served by these two kinds of food? Is the absorption of oxygen from the air always attended by the evolution of carbonic acid and water? How are these two compounds formed in the system? By what is this carbon and hydrogen supplied? What are the two kinds of food called?

stances, which go to supply the constant waste of the tissues, may be called the *elements of nutrition*.

633. The fat and oils found in animals appear to be stores of respiratory food, laid up by a wise foresight of nature for time of need. Thus, it is well known that when food is abundant the fat accumulates, which is again gradually wasted away when the supply of food becomes deficient. When the supply of food is wholly withheld from an animal, the fat rapidly disappears, its carbon and hydrogen going to supply the demands of respiration; and when this has all been consumed, the substance of the muscles is attacked, which become lean and flaccid, and lose their contractile power; and at length the brain and nerves yield to the same influence, and death speedily closes the scene of suffering. In animals that lie torpid during the winter, nature has provided that in the summer season a large accumulation of fat is laid up to supply the demands of respiration during the time they lie torpid in their dens; and, on the approach of the warm weather of spring, they are consequently found lean and weak.

We see, therefore, that the oxygen of the air is ever tending to consume all living beings, as really as if they were in a burning fire; in fact this consumption, which is a kind of combustion, is ever going on while respiration continues. To keep up the combustion, a constant supply of fuel is needed, which is found in the respiratory food, as before stated; and when these elements enter into combination within the animal system, heat is as necessarily developed

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633. What purpose do the fats and oils in animals serve? Under what circumstances do animals become fat? What becomes of this fat when the supply of food is deficient? What effects then follow after the accumulations of fat have been absorbed? What is said of animals that lie torpid during the winter? Does the oxygen of the air tend continually to consume all living beings? Is this consumption actually going on? How is the supply of fuel

as when the same thing takes place in the open air in ordinary combustion.

The accumulations of fat are formed when the supply of food is greater than the wants of the system demand; the amount of oxygen respired not being sufficient to oxydize entirely the carbon and hydrogen introduced into the system. Now, the quantity of oxygen taken into the system depends upon respiration, and will be increased by anything which renders the respiration more rapid, as frequent exercise, which is well known to be unfavorable to the fattening of animals intended for slaughter. It is well known also that energetic exercise of the system, while it raises its temperature by the more rapid respiration produced, at the same time increases the appetite for food; nature thus beautifully providing that the same cause which increases the quantity of oxygen respired shall also tend to the increase of the oxydable substances required for its neutralization in the system.

634. Besides the waste occasioned in the system by respiration, which we have seen is supplied by the non-nitrogenized or respiratory food, the various tissues are subject to a constant waste, and require to be constantly renewed. The matter for this purpose is supplied directly from the blood, and consists of the nitrogenized food, which is identical with the proteine compounds, and may be, as we have seen, either of vegetable or animal origin. The probability is, that these compounds, after the solution of the food in the stomach by means of the gastric juice, are absorbed unchanged, and conveyed to the blood, by which

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kept up? How does violent exercise affect the fattening of animals? How is this to be explained on the principles we have been discussing? How does exercise affect the temperature of the system? How does exercise usually affect the appetite for food?

634. Are the tissues of the animal system ever wasting away? By what kind of food is this waste supplied?

they are distributed to the different parts of the system, and appropriated to supply their waste.

It is important to notice that the composition of these substances is the same as that of the chief constituents of the blood, fibrine and albumen (571). It is probable therefore that, on being received into the blood from the food, they become incorporated into it, forming a part of its substance, to be again abstracted in supplying the waste of the tissues. The waste or worn-out matter from the tissues is separated from the blood by means of the kidneys, and, mixed with water, constitutes the urine.

The non-azotized or respiratory food is incapable of being converted into blood, but mixes with that fluid, and is by it distributed over every part of the system, where it comes in contact with the oxygen inhaled in respiration.

635. It has been a question whether the substances found in the animal system are produced by the animal organism, or whether they are all introduced ready formed in the food; but it is now admitted that many of them are formed in the system out of the materials supplied in the food. Thus, it is known that a lean goose, fed on Indian corn, will in a few days increase in weight several pounds, in consequence of the fat that will be formed in the system, which must have been contained in the corn, or formed from the substance of the corn by the organs of the animal. Now, that the most of it has been formed in the latter mode is certain from the fact that all the oil or fatty matter contained in the corn will amount only to a small fraction of the fat found in the goose. So bees will form wax when fed on pure honey or pure sugar. It has been found by

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635. What is said of the production of fat in a goose fed upon Indian corn? May not the fat of the goose have been obtained from the corn? What is said of the production of wax by bees when fed on honey or sugar?

experiment that for twenty parts of honey consumed they will form about one part of wax.

636. The process by which the food in the stomach and intestines becomes fitted to yield the requisite nourishment is called *digestion*. The food, after being masticated in the mouth and mixed with the saliva, passes into the stomach, where it is dissolved partially by the gastric juice (622), and is called *chyme*; it then passes into the small intestines and is mixed with the bile (624) and the pancreatic juice, by which it is made to separate into two portions; one of them, called *chyle*, being taken up by a set of vessels called *lacteals*, and carried to the blood, and the other portion being thrown off as useless.

637. *Nutrition of Plants*.—Animals, we have seen, require organic matter for their support; but plants are nourished by inorganic matter. They have the power of appropriating to their use the simple elementary substances, and assimilating them into their own substance. It might seem therefore that the nutrition of plants should have been discussed before that of animals; but though this might appear the natural order, we have preferred, for certain reasons, to delay the present topic to the last.

The proper germination of the seeds of most plants requires three conditions, viz: moisture, a proper degree of warmth, and the presence of atmospheric air. If any one of these is wanting, the seed will not germinate properly, whatever other favorable circumstances there may be. The proper degree of warmth is between 60° and 80° for most plants; but there is considerable diversity among them in this respect.

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636. What is digestion? What fluid secreted by the stomach dissolves the food? What is the chyle? How is the chyle conveyed to the blood?

637. Do animals require organic matter for their food? By

638. At first the seed swells much, and essential chemical changes take place in its substance, which consist, to some extent, in the conversion of the starch of the seed into sugar. This change is seen in the malting of barley, which consists in subjecting it to influences that cause it to germinate, and then suddenly checking its further growth by heat. This forms *malt*, which is found to contain more sugar and less of starch and other substances than before.

639. The young shoot is at first supported entirely by the substances contained in the lobes of the seed, but as soon as the roots are formed it draws its nourishment from the soil and air. We have already noticed (631) the beautiful provision by which the two great classes of organized bodies mutually compensate for the change each produces in the constituents of the atmosphere, and continue that proportion of them which is conducive to the healthful existence of both. Animals, during respiration, are constantly giving off carbonic acid; while plants, by the action of light, absorb carbonic acid and give off oxygen.

The carbon thus obtained by plants, and the water which is absorbed both by the roots and leaves, furnish the elements for woody matter, and other bodies, as sugar, starch, &c., which contain oxygen and hydrogen in the proper proportion to form water. But a much more complex action than this would imply, usually takes place. The absorption of carbonic acid and liberation of oxygen goes on only in the light: in the dark an opposite effect is produced, oxygen

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what are plants nourished? What three conditions are required for the germination of seeds? What is the proper temperature?

638. Do any important chemical changes attend the germination of seeds? In what is this change seen? In what does the process of malting consist?

639. From what does the plant at first derive its nourishment? What is the difference between animals and plants in the effects they are constantly producing upon the atmosphere? From what are the elements of the woody matter of plants furnished?

is absorbed and carbonic acid is given off; and the same effect is constantly produced by the colored portions, as the flowers and fruit. But it has been fully proved that, on the whole, the quantity of carbonic acid absorbed is much greater than that evolved, whilst the quantity of oxygen evolved is much greater than that absorbed.

640. But the proportion of nourishment derived from the air by different plants is no doubt exceedingly variable. Thus, several species of pine thrive well in mere sand that contains little or no decaying organic matter, and must therefore derive their nourishment chiefly from the air; but there are few plants of this character; most require to be situated in what we call a fertile soil—that is, a soil containing an abundance of matter that will serve for nourishment to them, in order that they may maintain a vigorous, healthy growth. So the sugar maple (*acer saccharinum*) yields its sap, which is little more than a weak solution of sugar, before it has even commenced putting forth its leaves in the spring, which are the organs by which the absorption of air is carried on. This sugar, therefore, or rather its elements, must have been absorbed from the soil.

641. Nitrogen, it is now well known, forms a necessary element of many vegetable substances; and, like carbon, is probably absorbed partly from the air and partly from the soil. This element, it will be recollected, constitutes nearly four-fifths of the whole atmosphere; but besides this a small portion is always present in the air in the form of ammonia, and in the same form it is also supplied to the

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640. Do all plants draw a like proportion of their nourishment from the air? What is said of several species of pine? Do most plants require a fertile soil for their healthy growth? What is said of the sugar maple in this connection?

641. Is nitrogen absorbed by plants? What proportion of the atmosphere is nitrogen? In what other form is it also present in the air?

roots of plants in the soil. Many organic manures, which consist in part of putrefying animal matter, afford a large supply of it; and it is to this agent, probably, that they owe their efficiency.

642. Besides the organic matter of plants, various inorganic substances, as alkaline and earthy salts, are always found contained in them, and no doubt serve an important purpose. These salts are obtained from the constant disintegration of the matter of the soil itself, and also from substances used as manures. Most plants contain in them salts of potash, which are found as carbonate of potash in the ashes after combustion; but in many plants that grow on the sea-shore soda is found to take the place of the potash. In the grasses and grains much silica is usually found, which seems to be required chiefly to give sufficient strength to the straw. The proportion of inorganic matter contained in any plant is shown by the quantity of ashes remaining after the organic portion has been consumed.

643. As these inorganic substances are necessary for the proper growth of plants, and all plants do not require the same substance, the reason is plain why the cultivation of certain crops is found so much more successful in some soils than in others. Thus wheat, which contains silica, lime, magnesia, potassa, and phosphoric acid, could not be expected to flourish in a soil destitute of potassa and phosphoric acid. We see, too, why bone-dust and wood-ashes, containing, as they do, the substances wanting in the soil for the production of this crop, should be found greatly to promote its growth, and become, under the circumstances, powerful fertilizers.

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642. Do plants require inorganic matter for their support? What salts do most plants contain?

643. Do all plants require the same substances for their nourishment?



644. The object and use of manures have been in part anticipated by the remarks above. Every substance is called a manure which, applied to a soil, increases its productiveness. In a particular case it may be a substance which is required in the proposed crop, but of which the soil is deficient; or it may be a substance designed merely to give the soil a proper texture, so that it may more easily be penetrated by the rootlets of the plants, or to increase its adhesiveness to enable it to retain longer the moisture that falls upon it. It is in the manner last mentioned, probably, that most mineral manures, as lime, marl, &c., usually operate.

645. From the preceding remarks, the great advantage of a proper *rotation of crops* may readily be seen. The mineral constituents of a soil are derived from the disintegration of its subjacent rocks; and some of them being contained only in small quantities, by continued succession of the same crop may be entirely removed, and the soil become impoverished. By substituting another crop which requires little or none of the material which has been exhausted, an abundant harvest may perhaps be obtained; and the soil, by the gradual decomposition of its subsoil, recover its former constitution. Indeed, a succession of crops may be so arranged, that, instead of impoverishing a soil, it will be gradually enriched, by the additions made to its organic components by the roots and rejected parts of the various crops left upon it.

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644. What are manures?

645. May some of the constituents of a soil be removed by the successive growth of the same crop year after year? How may this result be avoided?

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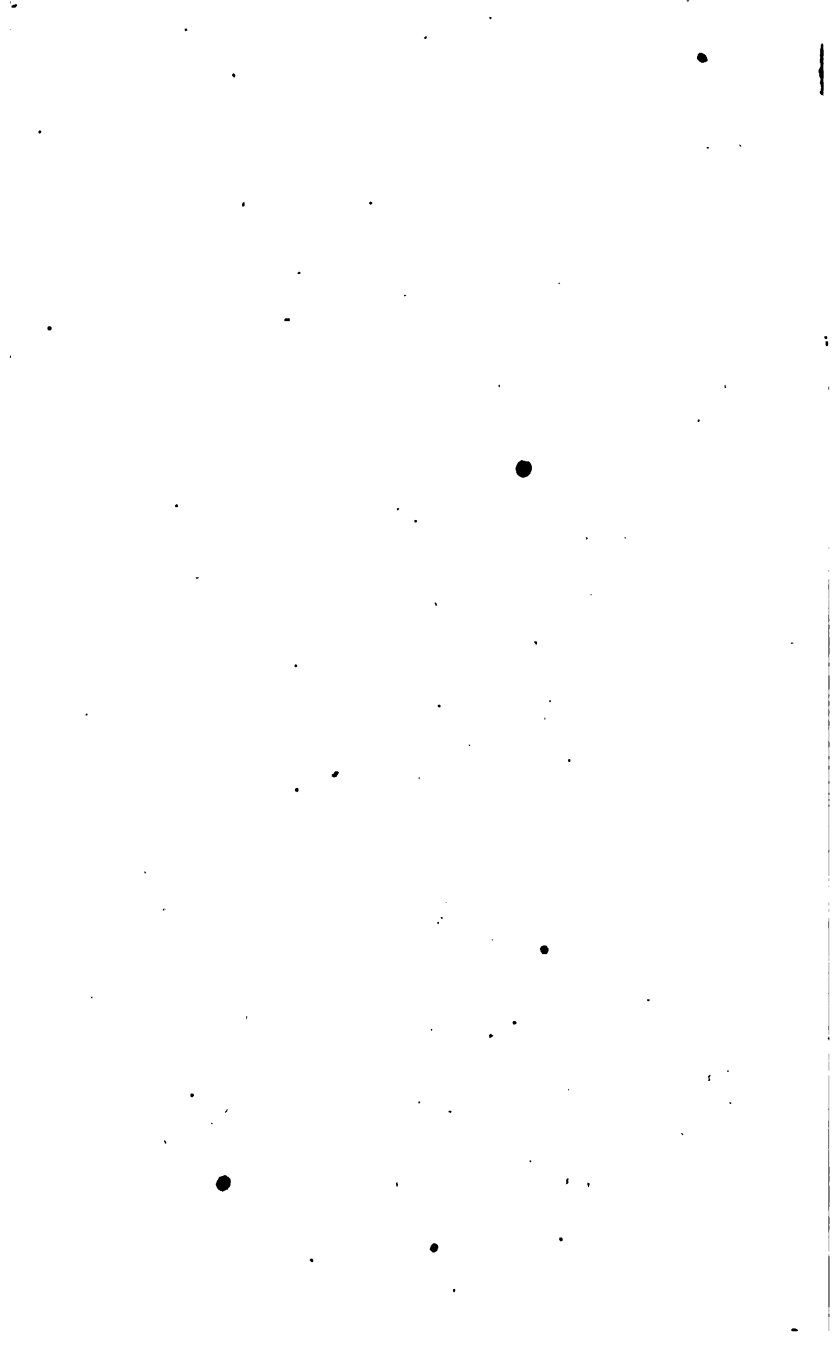
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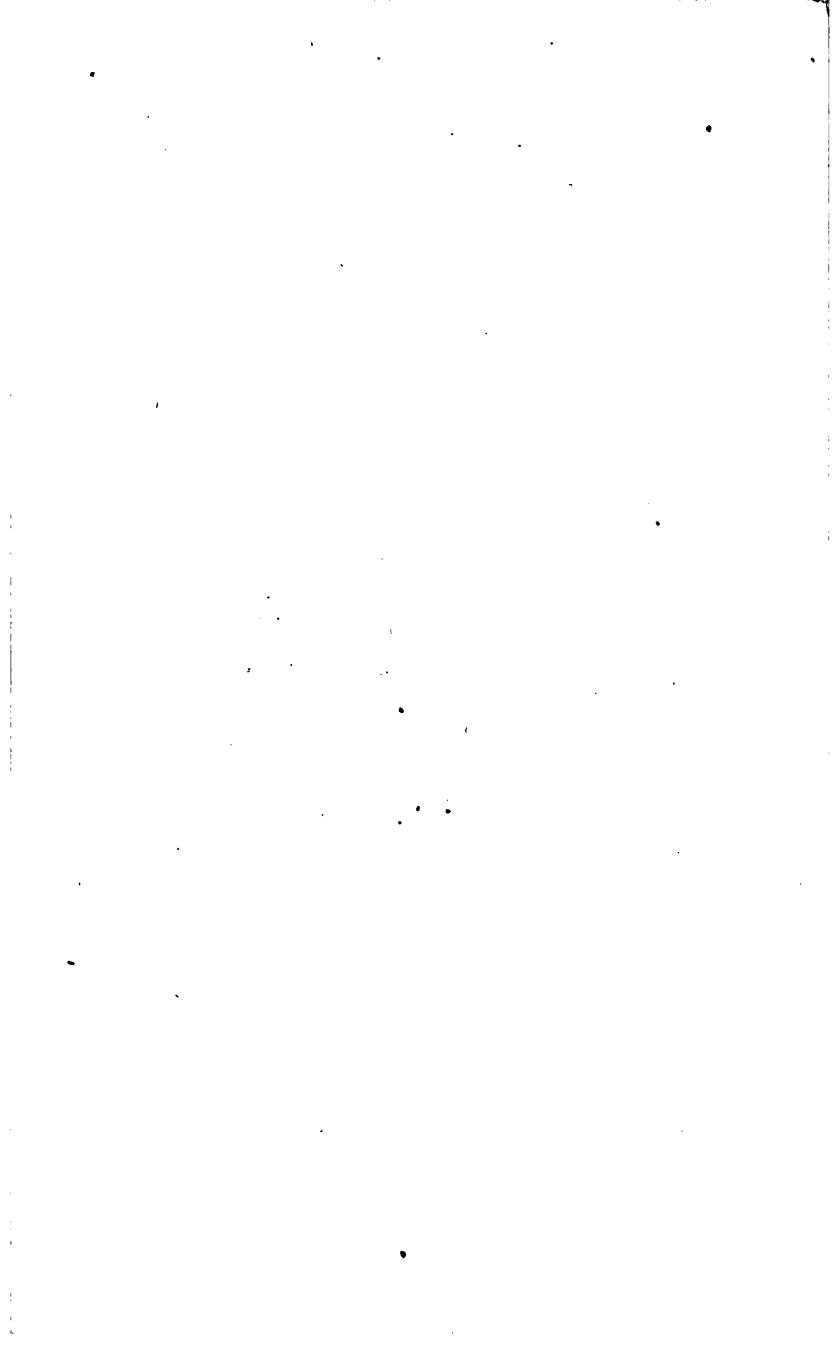
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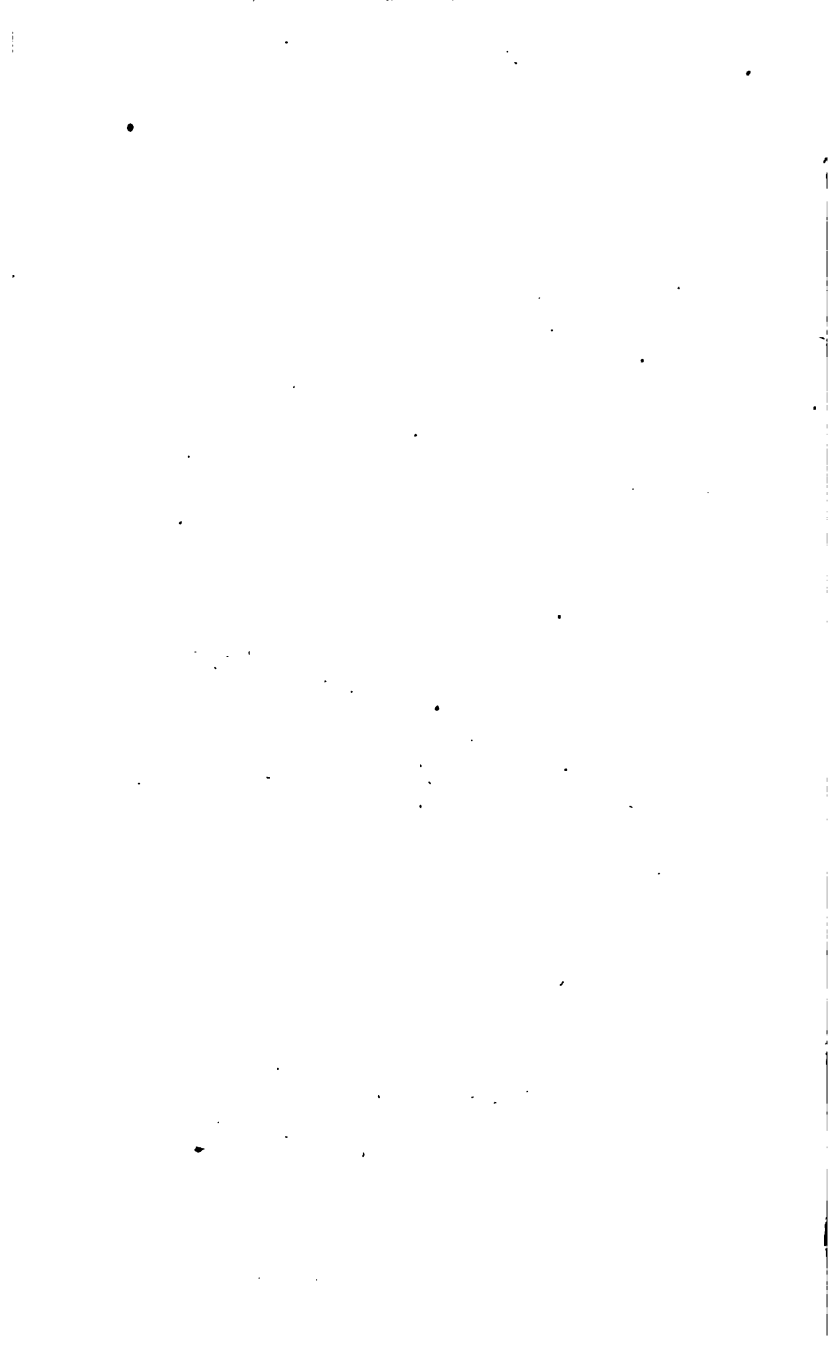


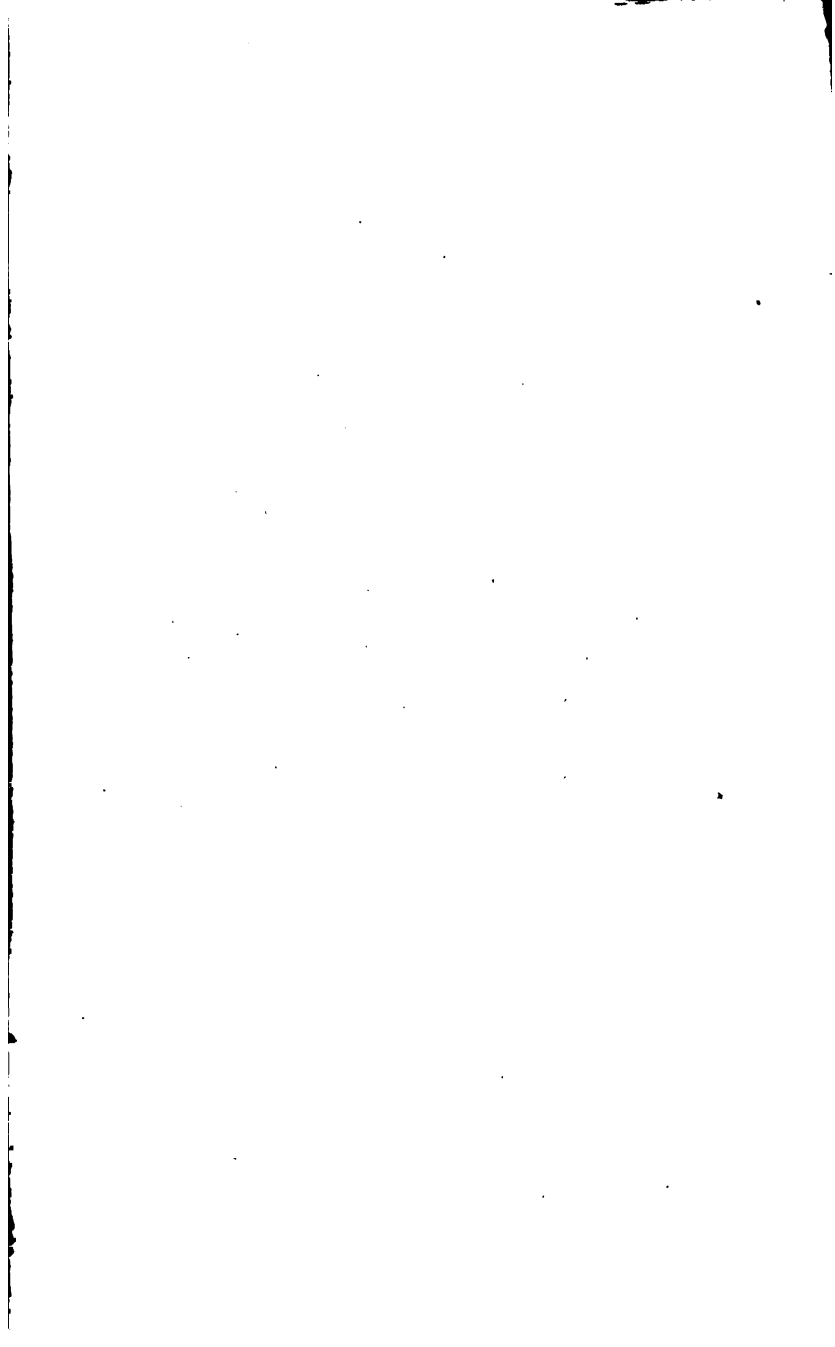
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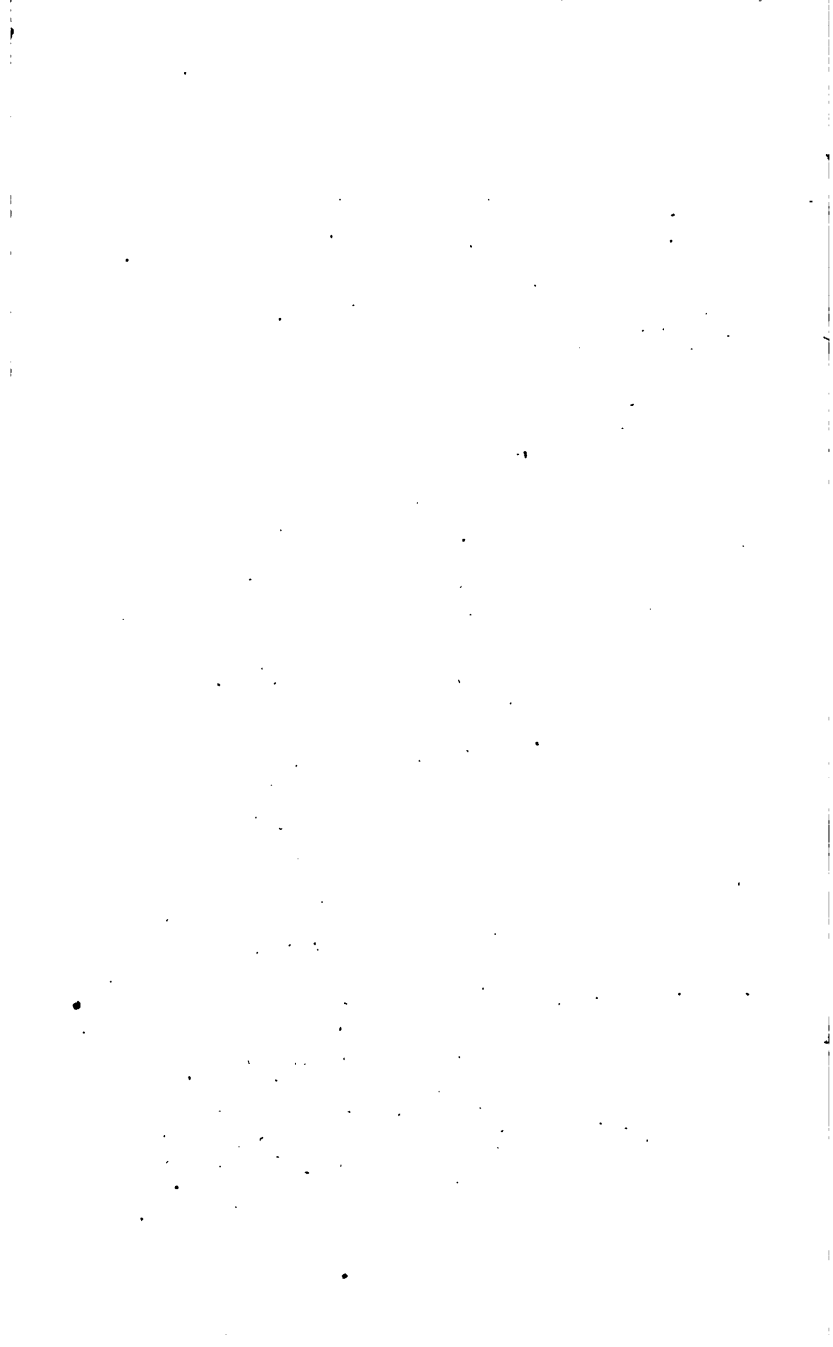
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when electricity is used through a wire  
to R. 217 St.

